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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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Head, Wrightson & Co., LIMITED. See Advertisement page 88, Aug. 27. 8402

Taylor & Challen Presses. 8195 TAYLOR & CHALLEN, LTD., Engineers, Birmingham. See Full Page Advertisement, Aug. 20.

Matthew Paul & Co., Ltd. LEVENFORD WORKS. **Dumbarton,** 8233 See Full Page Advt., page 78, Aug. 20.

Newcastle Shipbuilding Co., LIMITED, HEBBURN-ON-TYNE. Telegraphic Address: "Watertight, Hebburn." Telephones: Hebburn 83, 84, 85, 86. BUILDERS OF PASSENGER, CARGO AND OIL TANK STEAMERS. Licensees to build under the ISHERWOOD SYSTEM. Capacity of Shipyard: 10 BUILDING BERTHS UP TO 550 feet. RIVER FRONTAGE, 1500 feet.

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See Advt. Page 130, Aug. 27. **Steam Hammers** **Power Hammers** **Steam and Friction** **Drop Stamps.** **B. & S. Massey, Ltd.,** 3233 MANCHESTER.

The Manchester Steam Users' ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
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Founded 1854 by SIR WILLIAM FAIRBAIRN.
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SCHOOL OF ENGINEERING.

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The DAY DEPARTMENT reopens on 14th September, 1920.
Entrance Examination, 13th September, at 10 o'clock.
Three Year DIPLOMA COURSES in MECHANICAL ENGINEERING, ELECTRICAL ENGINEERING, MOTOR CAR ENGINEERING, CIVIL ENGINEERING.

Practice in the Laboratories, Drawing Office, Workshop and Field.
Fees 21 Guineas per annum.
The EVENING DEPARTMENT reopens on 27th September, 1920.
Students enrolled on 13th September, 6 to 8.30 p.m.
Detailed Prospectus of Day and Evening Department 2d. post paid, from the DIRECTOR OF EDUCATION. J 389

PATENTS AND DESIGNS ACTS, 1907 AND 1919.

Notice is Hereby Given that

FREDERICK HENRY ROYCE, and ROLLS-ROYCE, LIMITED, both of Nightingale Road, Derby, in the County of Derby, seek leave to amend the Specification of Letters Patents No. 130099 granted to them for "Improvements in Cylinders of Internal Combustion Engines."
Particulars of the proposed amendment were set forth in the Illustrated Official Journal (Patents), issued on the 26th August, 1920.
Any person, or persons, may give notice of Opposition to the Amendment by leaving Patents Form No. 19 at the PATENT OFFICE, 25, Southampton Buildings, London, W.C. 2, within one calendar month from the date of the said Journal.

W. TEMPLE FRANKS,
Comptroller-General.
J 540

Inst. C.E. Exams.—Over 300

successes by Correspondence Coaching. Several prizes. Sec. "U" now prepared. (Designs, Specifications and Quantities). A few vacancies open.—Address, 7434, Offices of ENGINEERING.

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B.Sc., Inst. C.E., I. Mech. E., all ENGINEERING EXAMS. Special Courses and Single Subjects. Personal tuition.—For full particulars apply to MR. TREVOR W. PHILLIPS, B.Sc. (HONS.), Assoc.M.Inst.C.E., M.R.S.I., etc., 9-10, Trafford Chambers, 56, South John Street, Liverpool. 8433

Inst. C.E., I. Mech. E., B.Sc.,

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Tuition by Post. — Rapid

COACHING for the October Examinations of the I.C.E. and I.M.E. 98% passes last exam. Estab. 1878.—PENNINGTONS, University Tutors, 304, Oxford Road, Manchester. 7963

TENDERS.

THE SOUTH INDIAN RAILWAY COMPANY, LIMITED, are prepared to receive

Tenders for the Supply of

STEEL TYRES for Locomotives and Rolling Stock (about 2500).
Specifications and Forms of Tender may be obtained at the Company's Offices, 91, York Street, Westminster, S.W. 1.
Tenders addressed to the Chairman and Directors of the South Indian Railway Company, Limited, marked "Tenders for Tyres," must be left with the undersigned not later than 2 p.m. on TUESDAY, the 28th SEPTEMBER, 1920.
A charge, which will not be returned, will be made of £1 for each copy of the Specification.
Copies of the drawings may be obtained at the office of Robert White, Esq., M.Inst.C.E., 3, Victoria Street, Westminster, S.W. 1.

By Order,
W. B. REYNOLDS,
for Managing Director.

91, York St.,
Westminster, S.W. 1.
25th August, 1920. J 508

THE SOUTH INDIAN RAILWAY COMPANY, LIMITED, are prepared to receive

Tenders for the Supply of

VOLUTE AND HELICAL SPRINGS (about 5,000).
Specifications and Forms of Tender may be obtained at the Company's Offices, 91, York Street, Westminster, S.W. 1.
Tenders addressed to the Chairman and Directors of the South Indian Railway Company, Limited, marked "Tenders for Springs" must be left with the undersigned not later than 2 p.m. on Wednesday, 29th September, 1920.
A charge, which will not be returned, will be made of £1 for each copy of the Specification. Copies of the Drawings may be obtained at the Office of Robert White, Esq., M. Inst. C.E., Consulting Engineer to the Company, 3, Victoria Street, Westminster, S.W. 1.

By Order,
W. B. REYNOLDS,
for Managing Director.

91, York Street,
Westminster, S.W. 1.
25th August, 1920. J 509

BARODA STATE RAILWAYS.

Tenders are Invited for 600

TONS FLAT FOOTED RAILS (B.S.), 20 lbs. per yard, with 16 tons FISHPLATES. Form of Tender, Schedule and Specification, with general conditions of Contract, may be obtained from the Consulting Engineers, Messrs. RENDEL, PALMER AND TRITTON, 12-14, Dartmouth Street, Westminster, S.W. 1, on payment of the sum of £1 1s. (which will not be returned). Tenders must be delivered at the above address not later than Noon, on Thursday, 9th September, 1920. J 536

PLANT FOR SALE.

THE GRAVESEND CORPORATION invite

Tenders for the Purchase and

REMOVAL of Two 150-200 Kilowatt Three-crank, Compound, Single-acting, Alley & MacLellan STEAM GENERATING SETS, direct coupled to Lancashire Dynamos, 460-500 volts, 400 revs. per minute, steam pressure 160 lbs.
Sealed Tenders addressed to the TOWN CLERK, 4, Woodville Terrace, Gravesend, and endorsed "Tender for Plant," to be received on or before 27th September, 1920.
Further particulars and permit to inspect may be obtained from the undersigned.
The Corporation do not bind themselves to accept the highest or any Tender.

BOROUGH ELECTRICAL ENGINEER,
Suffolk Road,
Gravesend. J 507

BOMBAY, BARODA AND CENTRAL INDIA RAILWAY COMPANY.

The Directors are prepared to receive up to noon on Friday, 17th September,

Tenders for the supply of

CAST IRON BEARING PLATES.
Tenders must be made on forms, copies of which with specification, can be obtained at these offices on payment of 20s. each (which will not be returned).
The Directors do not bind themselves to accept the lowest or any tender.

S. G. S. YOUNG,
Secretary.

Offices:—91, York Street,
Westminster, S.W.1.
1st September, 1920. J 510

LONDON COUNTY COUNCIL.

Tenders are Invited for the

SUPPLY and DELIVERY of 1500 Tons of MILD STEEL CONDUCTOR RAILS of plain tee section. Persons desiring to tender may obtain the drawings, specification, form of tender, etc., on application to the Chief Engineer of the Council, County Hall, Spring Gardens, S.W., upon payment to the Cashier of the Council, of the sum of £2. This amount will only be returnable if the tenderer shall have sent in a bona fide tender, and shall not have withdrawn the same. Full particulars may be obtained at the County Hall before payment of this fee. No tender, received after 4 p.m. on Monday, 20th September, 1920, will be considered. The Council does not bind itself to accept any tender.

JAMES BIRD,
Clerk of the London County Council.
J 507

TYNEMOUTH CORPORATION ELECTRICITY WORKS.

TRIPLE EXPANSION STEAM DYNAMO AND BOILERS FOR SALE.

The following Plant is for

SALE by TENDER—
One 500 k.w. Shunt and Compound Dynamo, 440 to 550 volts, by Siemens, coupled to triple expansion engine by Bellis & Morcom.
Two Exhaust Steam Oil Separators.
One Surface Condensing Plant by the Wallsend Slipway & Engineering Co., Ltd., with Edwards three throw Air Pumps, direct driven by Electric Motor.
One Centrifugal Circulating Pump for same, direct driven by Electric Motor.
One Cooling Tower for same.
Four Lancashire Boilers 30 ft. by 8 ft. 6 in., 150 pounds working pressure with mechanical stokers and three fitted with superheaters.
One Climax Watertube Boiler suitable for 15,000 pounds per hour, 200 pounds working pressure.
9 in. Steel Steam Pipes and Valves connected with the above.
Three Weir Feed Pumps, Feed Pipes and Valves connected with the above.
Two 3 in. Invincible Centrifugal Pumps by Gwynne & Co., 3 in. bore, electrically driven.
One Vertical Duplex Pump by Lamont & Co., Paisley, cylinders 5 in., stroke 6 in., suction 3½ in.
Coal Bunkers and Conveyor with Motors.
The above are for sale at Tynemouth Corporation Electricity Works and may be seen by appointment.
For further particulars apply to C. TURNBULL, M.I.E.E., Borough Electrical Engineer, Tynemouth. J 320

APPOINTMENTS OPEN.

UNIVERSITY OF LONDON, KING'S COLLEGE.

DEPARTMENT OF ENGINEERING.

The Delegacy Require the

SERVICES of a LECTURER in civil and Mechanical Engineering, to take up his duties on 1 Oct., Salary £450. Applications with copies of three recent testimonials should be sent not later than 22nd September to the SECRETARY, King's College, Strand, W.C. 2, from whom further particulars may be obtained. J 504

WIGAN AND DISTRICT MINING AND TECHNICAL COLLEGE.

Applications are Invited for

the following VACANCY:—
LECTURER IN ENGINEERING.
Salary scale.—£35—£10-£300—£15-£500.
In fixing initial salary full allowance will be made for years of service.
Particulars may be had from the PRINCIPAL to whom applications should be sent as early as possible. J 543

COUNTY BOROUGH OF WEST HAM.

MUNICIPAL TECHNICAL INSTITUTE.
Romford Road, Stratford, E. 15

Two Full-Time Assistant

LECTURERS and DEMONSTRATORS in Mechanical Engineering WANTED for next Session.
Salary £300—£15—£325 per annum.
Must be graduates of British University.
Applications, with particulars of qualifications and copies of recent testimonials, should be sent to the PRINCIPAL, Municipal Technical Institute, Romford Road, E. 15, not later than 5th September, 1920. J 190

CITY OF LINCOLN MUNICIPAL TECHNICAL SCHOOL.

A. B. COLLIS, M.I.M.E., Principal.

Applications are invited for

an ADDITIONAL LECTURER in the Mechanical Engineering Department. Candidates will be required to take day and evening classes. University degree or equivalent qualification desirable.
Workshop and Drawing Office training, teaching experience, and good experience in Engineering Laboratory essential.
Commencing salary £325, rising by annual increments of £12 10s. to £400.
Form of Application and further particulars may be obtained from the PRINCIPAL, to whom applications should be returned as soon as possible. J 437

CITY OF BRADFORD EDUCATION COMMITTEE.

TECHNICAL COLLEGE.

Applications are Invited for

a LECTURESHIP in Engineering Drawing. Salary (including War Bonus of £86 16s.) up to £400 per annum to a candidate of suitable qualifications and experience.
Applications upon forms which may be obtained from the PRINCIPAL, Technical College, Bradford, should be forwarded to the Principal as soon as possible.

BY ORDER.

18th August, 1920. J 431

COUNTY BOROUGH OF STOKE-ON-TRENT.

CENTRAL SCHOOL OF SCIENCE AND TECHNOLOGY, STOKE-UPON-TRENT, ENGINEERING DEPARTMENT.

The Governors invite

Applications for the Post of

LECTURER in MECHANICAL ENGINEERING.
Candidates should hold a University Degree or an equivalent qualification, and must also have had teaching and works experience.
The commencing salary will be £350 to £400 per annum.
Forms of Application, which should be returned, duly completed, as early as possible, and further particulars may be obtained on receipt of stamped, addressed foolscap envelope from

DR. W. LUDFORD FREEMAN,
Director of Education.

Education Offices, Town Hall,
Hanley,
Stoke-on-Trent.
30th July, 1920. J 386

EGYPTIAN MINISTRY OF EDUCATION.

DEPARTMENT OF TECHNICAL, INDUSTRIAL AND COMMERCIAL EDUCATION.

Applications are Invited for

the following VACANT POSTS in the Government School of Engineering. These posts are on a contract of three years. The annual salary is stated in Egyptian Pounds (£E. 1 = £1 0s. 6d.). The posts also carry a temporary War Gratuity of £E. 16 a month. An allowance is given for journey to Egypt.

LECTURER IN APPLIED MATHEMATICS and MECHANICS, £E. 576.
ASSISTANT LECTURER in APPLIED MATHEMATICS and MECHANICS, £E. 504.
LECTURER in PHYSICS, £E. 576.
ASSISTANT LECTURER in PHYSICS, £E. 504.
LECTURER in ENGINEERING MATERIALS and STRUCTURES, £E. 576.
LECTURER in DESCRIPTIVE GEOMETRY and MECHANICAL DRAWING, £E. 576.
INSTRUCTOR in DESCRIPTIVE GEOMETRY and MECHANICAL DRAWING, £E. 432.

Applicants must possess a University Degree or its equivalent, and some teaching experience is essential.
Further particulars may be obtained from the DIRECTOR, of the EGYPTIAN EDUCATIONAL MISSION, 26, Victoria Street, Westminster S.W., to whom application should be made not later than the 18th September. J 535

SURVEY DEPARTMENT, GOLD COAST COLONY.

Applications are Invited

for Pensionable Appointments as SURVEYORS and as INSTRUCTORS (including CHIEF INSTRUCTOR) in SURVEY and MATHEMATICS at a SURVEY SCHOOL in process of formation for Natives. Starting salary according to qualifications and experience on the scale £480 to £920 a year, rising by annual increments of £30 to £720, thence by £40, with a charge allowance of £72 added after £730. Prospects of promotion by selection to higher rates. Free furnished quarters, or an allowance in lieu. Liberal allowances when travelling. Leave at the rate of 5 days vacation leave for each calendar month of service, followed by 5 days per month return leave if returning for further service. Free passages both ways. A tour of service normally lasts 8 or 12 months, according to the exigencies of the service.
Candidates who have had practical experience of survey work, or who have passed the A.M.I.C.E. Examination, or who have received a good mathematical or engineering education at a University, should apply at once, by letter, to the CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W. 1, quoting M/10,184. Candidates must have served in some branch of His Majesty's Forces during the late war, unless satisfactory reasons for not having done so can be furnished. J 577

COUNTY BOROUGH OF BARROW IN FURNESS.

TECHNICAL AND JUNIOR TECHNICAL SCHOOLS.
Principal—D. HARDMAN, M.Sc

Applications are Invited for

the POST of TEACHER OF ENGINEERING SUBJECTS. (Graduate or equivalent qualifications).
Salary according to experience and qualifications. Max. £450.
Further particulars may be obtained from the Director of Education, Town Hall, to whom applications should be forwarded on or before 14th September, 1920.

By Order,
L. HEWLETT,
Town Clerk and Clerk to the
Local Education Authority.

Town Hall,
30/8/1920. J 542

PORT OF LONDON AUTHORITY.

ENGINEERING DIVISION.

The PORT OF LONDON AUTHORITY are prepared to receive

Applications for the Appoint-

MENT of ASSISTANT MARINE ENGINEERING SUPERINTENDENT. Candidates, whose age must not exceed 36 years, must be Corporate Members of the Institution of Naval Architects and possess suitable qualifications. Also they must have been trained as Marine Engineers and have considerable experience in the design, construction and repair of dredging plant, tugs and other harbour service craft, both in respect to hulls and machinery. Sea-going experience, whilst not essential, is desirable.
Particulars of the conditions of service will be found on the Form of Application, which may be obtained at the office of the Chief Engineer, 109, Leadenhall Street, E.C., to whom all applications must be addressed and delivered not later than Noon on Monday, 4th October, 1920.

C. E. S. KIRKPATRICK,
M.Inst.C.E.
Chief Engineer.

31st August, 1920.
109, Leadenhall Street, E.C. 3. J 558

General Works Manager.—

The ENGLISH ELECTRIC CO., LTD., Require the Services of a GENERAL WORKS MANAGER, whose duties will be to control under a Managing Director the several Works of the Company situated in PRESTON, COVENTRY, RUGBY, STAFFORD and BRADFORD.
While experience in the manufacture of large Power Units and Electrical Machinery is very desirable, a long experience in the organisation and works management of one or more large Engineering Works is essential.
Applications, which will be treated in confidence, should be addressed to the JOINT MANAGING DIRECTORS, ENGLISH ELECTRIC CO., LTD., Queen's House, Kingsway, W.C. 2. J 132

SOUTH INDIAN RAILWAY COMPANY LIMITED.

The Directors are prepared to receive written

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QUALIFIED Candidates for the APPOINTMENT of an ASSISTANT ENGINEER on the Company's Staff in India. Candidates who may be between the ages of 24 and 30 years must have received a sound, general and technical education followed by pupilage with a Civil Engineer engaged in constructional work or as Engineer to a British Railway Company. Candidates must also have passed the Associate Membership Examination of the Institution of Civil Engineers or have taken a degree exempting from such examination. The terms of the appointment are a three years' agreement in the first instance commencing on a salary of 450 rupees per mensem and rising by annual increments of 50 rupees per mensem for each year of approved service to 800 rupees in the eighth year. The Company will provide a first-class passage to India, and the salary will commence from the day of sailing.
Preference will be given to candidates who have had railway experience or who have served during the late war.
Applicants must give a full chronological record of their career, stating whether they are married or single, and including details of their education, training and subsequent civil or military experience.
Applications must be addressed to the Company's Consulting Engineer, ROBERT WHITE, Esq., M.Inst.C.E., 3, Victoria Street, Westminster, S.W.1. J 534

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the Manchester Steam Users' Association, a PRACTICAL ENGINEER, age 25 to 35, conversant with the construction of boilers and steam plants, to fill the position of inspector; the duties will require him to examine boilers internally and also to go up the flues; he must be capable of taking boiler dimensions, making sketches of boilers, and drawing up reports. Commencing salary £250 per annum. Apply by letter, stating age, experience and previous engagements, &c., to the SECRETARY, 9, Mount Street, Manchester. J 559

THE MACHINE TOOL AND ENGINEERING EXHIBITION AT OLYMPIA.

Many of the branches of the engineering industry have held important trade exhibitions since November, 1918. Up to the present, however, the electrical and machine tool industries have not been specifically represented in this way. The omission as far as machine tools are concerned will be rectified to-morrow when the Machine Tool and Engineering Exhibition opens at Olympia. The electrical branches of the engineering industry are, we think, to hold an exhibition next year. The period which has elapsed since the Armistice is now approaching two years, but an exhibition such as the present cannot be arranged in a few weeks and the first half of the two years period was so unsettled from an international point of view that those responsible would naturally hesitate actively to proceed with an exhibition of this character. A minor but very actual consideration which may have dictated the postponement until the present is the pressure on the very few buildings which are available. An exhibition of this kind demands a large amount of preparation on site and the employment of Olympia for a considerable number of weeks. It, at the same time, demands much transport of heavy material, and it is doubtful if the railways could have dealt with the work a year ago. As it is, we understand they have been not too anxious to help, and without the assistance of the commercial steam and petrol lorry it is very doubtful if the machines at present collected at Olympia would have been where they now stand.

The exhibition has been promoted by the Machine Tool Trades Association, Incorporated, a body which includes most of the important machine tool manufacturers of the country. As a result it is of an official nature and few of the firms in the trade will be found to be missing. The Machine Tool Trades Association has as a matter of policy avoided continual minor exhibitions and has held that really important shows at longer intervals are productive of more good. This explains the fact that the last exhibition organised by the Association was held as long ago as October, 1912. The interval between that exhibition and the present one is, of course, longer than would have been the case had there been no war. The long interval has advantages from the point of view of the visitor to the present exhibition, in that he will have an opportunity of seeing a very large number of new machines and models. The occurrences of the war period have also tended to make the exhibition unusually interesting. Those occurrences brought home the advantages of repetition methods to the British manufacturer in quite a new way, and the outcome of those lessons is very clearly to be seen in the machines collected at Olympia. It is to be hoped that the manufacturer will realise anew from his visits to the show that many of the industrial methods good in war are good also in peace. It is also to be hoped, or at any rate wished, that a fair number of workpeople may do likewise. We note that a Conference is to be held at Olympia on the 21st inst. on "Unemployment and Production" and that Mr. G. N. Barnes is to speak. We trust many working men will make that an opportunity to visit the show.

In this our first notice of the exhibition it has not been possible to deal completely with any specific type of exhibit, since only actual inspection of the exhibition in being could enable anyone to do that. Our notice accordingly takes the form of the description and illustration of numbers of the machines. These we have divided into groups each dealing with some one class of machine. This appears the most convenient arrangement both for our readers and ourselves. The only danger in the matter is that it should be supposed these groups are exhaustive. This is far from being the case and undoubtedly we shall in the coming weeks have to deal with further examples of machines belonging to all the classes of which we now treat. The only thing further to be said by way of introduction has reference to the impressions which the exhibition as a whole makes on one interested in machine tool design and the tendencies it may seem to illustrate in the progress and development of that design. These matters we shall, no doubt, be expected to refer to, and we will endeavour to do in due course. They can, however, only be satisfactorily handled after we have had an opportunity of seeing the complete display. For this week we must leave this aspect of affairs and may at once proceed to a description of such of the exhibits as we are now able to illustrate.

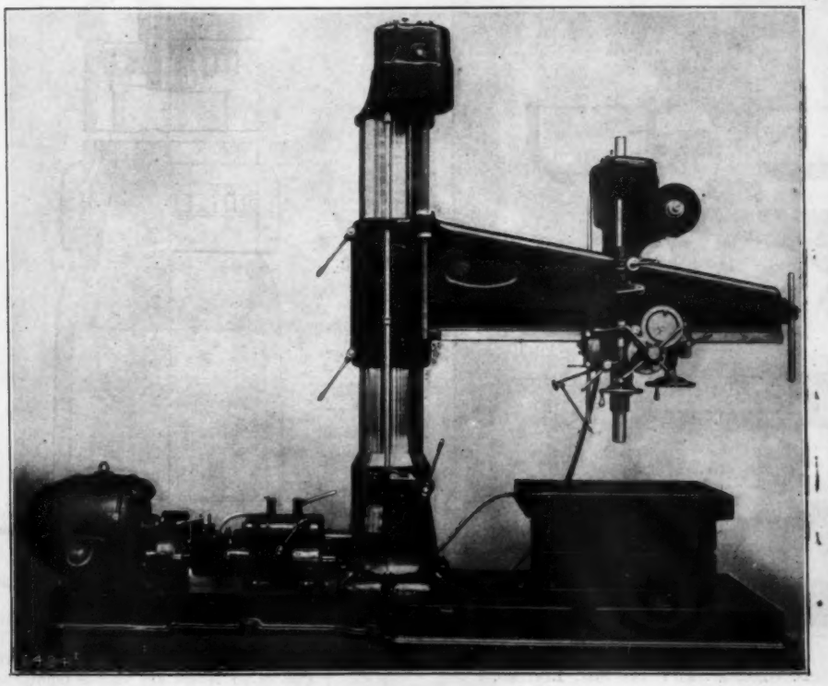


FIG. 1. CENTRAL THRUST 6-FT. RADIAL DRILL; MESSRS. GEORGE SWIFT AND SONS, LIMITED.

RADIAL DRILLING MACHINES.

IN this article we commence our description of the exhibition with some examples of radial drilling machines. A glance at representative tools shows two or three directions in which design appears to be trending. In the first place there is a definite movement towards centralised control at the saddle, though all designs do not go the same length in this matter. This, of course, is a great advantage when large jobs are on the machine, as it obviates the need of the operator walking round the projecting work to get at controls on the column or base. Another feature is the endeavour made to get as direct a thrust as possible from the spindle on to the arm, some designs going to the length of adopting the central thrust arrangement, which will probably become more popular in the future. Various typical examples are illustrated on the present page, pages 302 and 303 and Plates XXVII and XXVIII, accompanying this week's issue of ENGINEERING.

One of the central thrust type of radial drilling machines is shown by Messrs. George Swift and Sons, Limited, Halifax. This machine is illustrated in Fig. 1, annexed, which gives a very good view of the horizontal ways on which the upward thrust of the saddle on the under side of the arm is taken. The arm is double-walled with the spindle working between them. There is no doubt that there is a great deal to be said for this idea. This machine is a 6-ft. radial drilling, tapping and studding machine. The minimum radius to which the spindle can be run in is 1 ft. 9 in. The maximum distance between the spindle and baseplate is 5 ft., and the minimum 6 in., the arm having a rise and fall of 3 ft. 4 in. The spindle diameter is 3 in., bored to No. 5 Morse taper. The machine is fitted with a 10-h.p. constant speed direct-current 220-volt British Thomson-Houston motor. From the above particulars it will be evident the machine is designed for heavy work, though centralised control is not pushed so far in this design as in others we shall have to refer to. The drive from the motor to gear-box is by raw hide pinion, with friction gear so that speeds can be changed at any time without stopping the motor. The changes are obtained by interlocking levers on the gear-box. Eight speeds are obtained by means of the gear-box, and there are double gears on the saddle, giving 16 spindle speeds in all. The number of feeds is six, controlled by graduated dials on the saddle. The reverse motion to the spindle is controlled by a lever on the saddle. Automatic trips and depth regulation are provided for the feed, a dial for this control being placed on the front of the saddle. Safety trips are also fitted to the elevating mechanism.

A smaller machine of a different character by the same firm, is shown in Fig. 2, page 302. This is a 3-ft. 6-in. radial drilling, tapping and studding machine fitted with a low base and a swing table, 24 in. by 14 in. by 2 ft. 2 in. high. It is belt-driven, with a gear-box giving 12 speeds controlled by interlocking levers. The number of feeds is three, controlled at the saddle. The reverse motion is also controlled at the saddle. The maximum height from spindle to base is 4 ft. 3 in. in this machine, and the rise and fall of the arm 10 in., with a spindle feed of 10½ in.

One of the most interesting of the radial drilling machines is that shown by Messrs. Alfred Herbert, Limited, Coventry, being made for this firm by Messrs. Tangyes, Limited, Birmingham. This is a 4-ft. radial machine of several original features. We illustrate it in Fig. 3, page 302, and Figs. 4 to 7, Plate XXVII, which give respectively a drawing of the column, front and back views of the machine, and details of the arm, and saddle support. The machine will be seen to be electrically driven by a motor placed on a backward extension of the radial arm, which it partially balances. The drive thus obtained is greatly simplified, all motions being derived from a single running shaft coupled direct to the motor. This eliminates at once many of the parts required with the more usual designs of radials. The motor is a constant-speed reversible machine, the control being by a lever under the saddle. All speed and feed changes, and the reverse are effected from the saddle. The views we give will convey a good idea of the simplification which this form of drive makes possible.

Fig. 3 shows the arrangement for supporting the sleeve on the column. The column is bolted to a heavy baseplate, and is surrounded by a sleeve,

the weight of the latter being taken by a large ball bearing at the top, with side thrust roller bearings at the top and bottom. The freedom of rotation is remarkable; we have seen the sleeve, with the arm complete and motor mounted upon it, rotated merely by the grip of the hands round the barrel of the sleeve.

Figs. 6 and 7 show a plan of the saddle and arm, and an end view. These two illustrations show the three lines of support of the saddle on the arm. It will be seen that there are rollers on the top both at the front and on the back slides so arranged as to give extremely good support. The ease of movement of this saddle is also excellent. The arm is circular in cross-section. It is clamped and unclamped and the elevating motion engaged by a single lever at the column end of the arm to the front of the machine. It is thus impossible to engage the elevating movements while the arm is clamped.

The elevating motion is derived from the main horizontal shaft which drives a revolving nut on a stationary vertical shaft. The latter is at the back of the machine and therefore does not interfere with work being brought quite close up to the sleeve if necessary. The nut is driven by a worm and worm wheel through a clutch which is engaged by throwing over the clamping lever. The worm wheel rotates, of course, with the direction of the reversing motor, according as it is required to raise or lower the arm. Safety stops disengage the elevating gear at either end of its range.

The saddle carries all speed and feed change gears, all totally enclosed. The spindle has 16 speed changes, ranging from 28 r.p.m. to 547 r.p.m. Eight changes are made by sliding gears; these are doubled by back gears. The sliding gears are of chrome-nickel steel, and run in an oil bath. The speed changes are obtained by levers with indicator discs on the front of the saddle. There are six spindle feeds, ranging from 31 r.p.m. to 140 r.p.m., which are obtained simply by rotating an indicator head. This is a very easy movement. The rotation of the head, seen in front of the saddle, brings into action one or another of various spring keys in the feed-gear shaft, only one key being in action at one time. These gears are made of chrome-nickel steel with worm gear of phosphor-bronze. Automatic stops to the feed in the form of an adjustable lever prevent over-running. The dial over which this lever works is graduated so that drilling to any depth can be repeated.

The machine is substantially built like all tools of Messrs. Herbert's design. The diameter of the column is 13 in.; the thickness of the baseplate 8 in. The smallest diameter of the spindle is 2 in. The arm will traverse 2 ft. 8 in. on the column, and the saddle will traverse 3 ft. 2 in. on the arm. The minimum height from the spindle to baseplate is 13 in., and the maximum 5 ft. The minimum distance from spindle to column is 12 in. The working surface of the baseplate is 4 ft. 4 in. by 3 ft., and a box table, 30 in. by 24 in. by 22 in. high, can be supplied if required. From the above figures the range of work of which this machine is capable will be seen to be a very wide one. The motor is of 5 h.p., and runs at 690 r.p.m.

A new model of the well known Archdale machines is illustrated in Figs. 8 to 11, Plate XXVIII. Messrs. James Archdale and Co., Limited, Birmingham, have a number of types on exhibition. They include a 3 ft. 6 in. and a 4 ft. radial drill, with rather different column and table arrangements. The machines we now illustrate are a 3-ft. 6-in. sensitive and radial drill, and a 32-in. sensitive and radial machine. The 3-ft. 6-in. machines have 18 spindle speeds, and 4 feeds. The smaller tool, which will be described later, has three spindle feeds, and hand feed only.

The machine illustrated in Figs. 8 to 11 is typical of Messrs. Archdale's designs, and embodies full centralised control, in which both speeds and feeds are changed by levers on the saddle itself. This is an advantage which Messrs. Archdale were one of the first firms to recognise, especially on large-sized drills, with which there is often much work to be done on castings, &c., which project awkwardly beyond the machine base. On such work the operator will frequently work at an incorrect speed, merely to save himself the trouble of walking some way to the gear-box. If the control be handy he will be much more likely to make the proper changes. This machine will be seen to be belt-driven, though electric drive is arranged, of course, if required. From the fast and loose pulleys the drive is transmitted to gears at the head of the column, and thence by spindles on the sleeve, to the arm. These spindles and shafts run at a constant high speed. The elevating motion for the arm is obtained by a small lever at the base of the sleeve. The movement of this lever controls both the elevating gear and the arm lock so that it is impossible to elevate with the arm locked, or *vice versa*. The most interesting features of these machines are embodied in the saddle. Figs. 8, 9 and 10 give three views of an Archdale saddle, the two former show the upper and lower portion of the saddle with the front covers removed, while the last shows the change-speed gear-box which is at the back of the upper part of the saddle. The front views show the hand and sensitive feed and the feed-change gears. The spindle rack is shown to the left of these views. The feed gears give four changes by a single lever working with spring stops over a quadrant. This lever is shown in both these views. There are stops between the meshing positions, thus enabling the gears to be held idle at any point between two steps. The spindle rack is driven by the worm wheel shown in Fig. 8. This drive is through a friction clutch which can be quickly disengaged or engaged by a small lever with a knob on it, seen to the right hand bottom corner of the saddle in Fig. 11. To the left-hand end of this feed spindle (Fig. 8) is a hand wheel for quick vertical racking motion for the main spindle. Below the worm and clutch is the hand wheel for the slow hand speed.

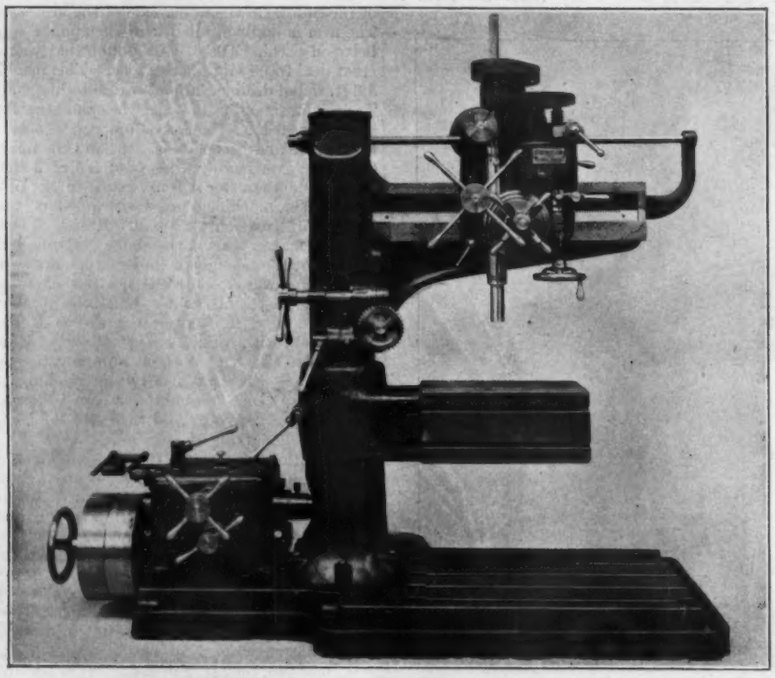


FIG. 2. 3-FT. 6-IN. RADIAL DRILL; MESSRS. GEORGE SWIFT AND SON, LIMITED.

Fig. 3.

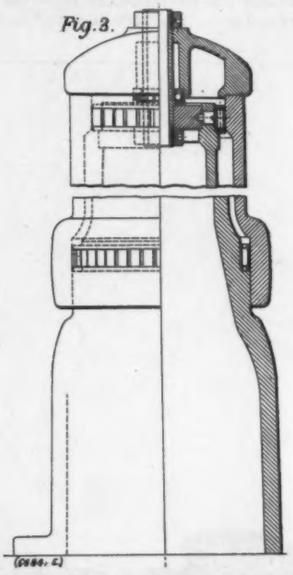


FIG. 3. COLUMN AND SLEEVE BEARINGS FOR HERBERT RADIAL DRILL.

The sensitive feed is by the vertical hand lever on the right of the saddle, ratcheting with the spur at the right-hand end of the feed driving spindle. Two other levers are visible pointing to the right at the lower end of the saddle. That furthest to the right is a lever for starting, stopping and reversing; the second is a combined saddle and sleeve locking lever. The latter enables the arm to be swung and the saddle set and then both to be locked by the one movement. The starting lever is carried in a housing up to the back of the speed gear-box, Fig. 10. This gear-box is worked by two levers with dial indicators, in the centre of the face of the saddle, Fig. 11. The box gives nine changes. The drive to the spindle is through the worms at the left-hand top corner of Figs. 8 and 10. The starting lever acts also on the reverse, enabling the spindle to be at once thrown out of gear and reversed at twice the forward speed. An automatic stop is fitted to the feed, and the spindle is graduated; further there is also safety gear to the arm elevating mechanism, to prevent over-running. The spindle is counterbalanced by chain and spring gear in the housing over the saddle.

The box table is hinged to the base and can be swung clear if necessary. It is provided with a handle with a clamp to hold it in position when in use. This machine has a radius as stated of 3 ft. 6 in. The saddle has a traverse of 29 in., and the vertical adjustment of the arm is 29 in. The maximum feed of the spindle is 12 in., and from the spindle to bedplate (not table) the maximum height is 4 ft. 6 in. The table is 32 in. by 27 in. by 21 in. high.

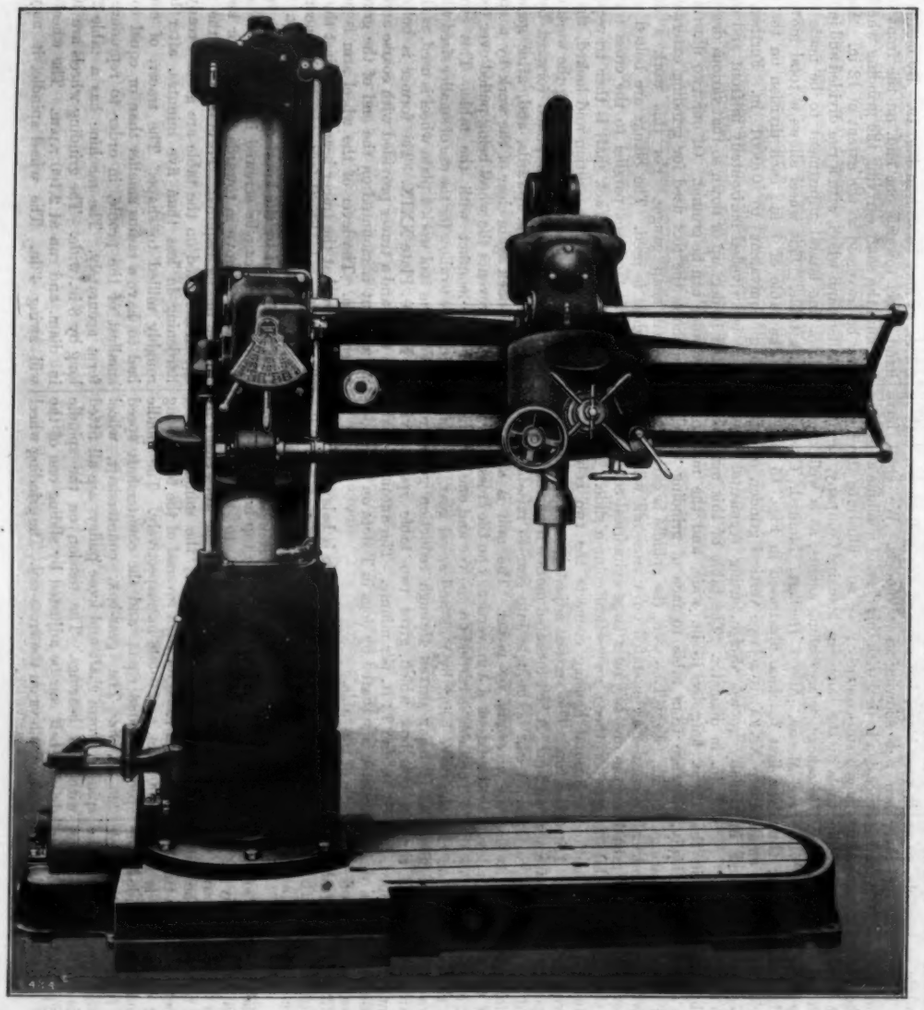


FIG. 13. HIGH-SPEED RADIAL DRILL; MESSRS. WILLIAM ASQUITH, LIMITED.

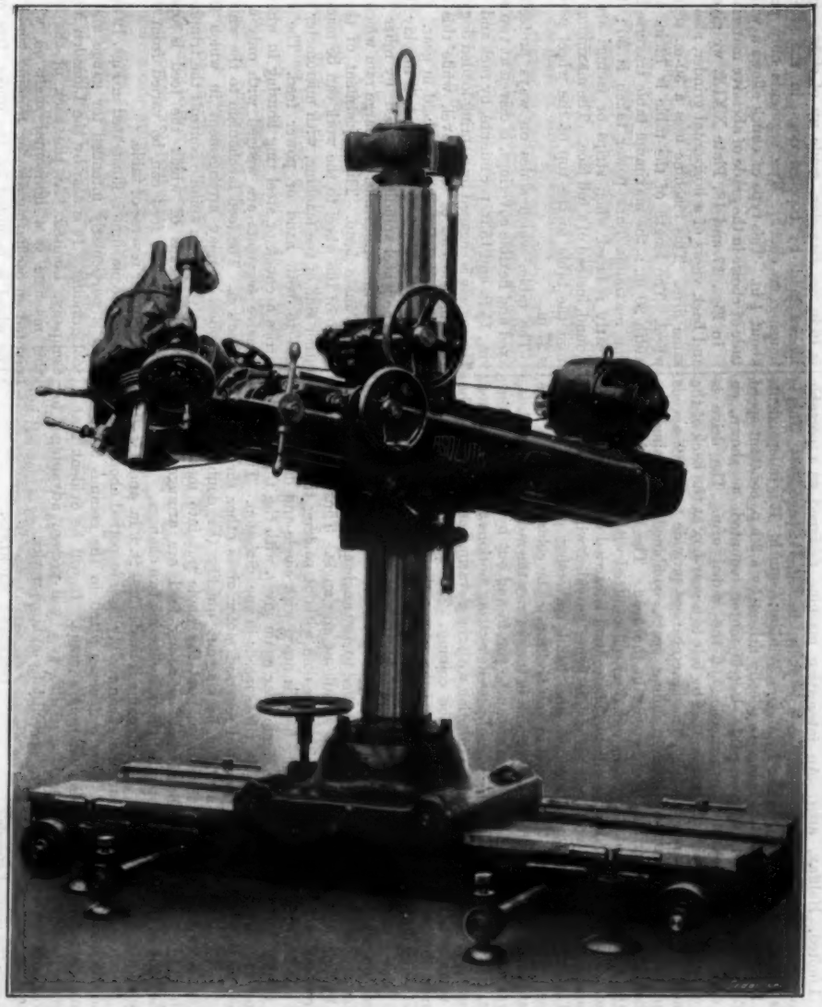


FIG. 14. PORTABLE UNIVERSAL RADIAL DRILL; MESSRS. WILLIAM ASQUITH, LIMITED.

The small radial drill by Messrs. Archdale is shown by Fig. 12, Plate XXVIII. This machine, which, as already stated, is of 32-in. radius, and being so much smaller and only for sensitive drilling, it is naturally of a more simplified character than the usual radial drill. The drive is by belt on to a fast-and-loose pulley, whence it is transmitted by a vertical shaft inside the column to the speed box at the head of the latter. The change gears in this box are operated by two levers giving nine spindle speeds. The radial arm swings on ball and roller bearings. The spindle has ball thrust bearings. The balance for the spindle is by compensated spring gear. The reverse is operated by a lever on the saddle and the sensitive feed is by means of hand lever and ratchet.

The work-table is of the elevating type, the motion being obtained by hand wheel with telescopic screws which serve to steady the table in any position in which it is clamped. In place of the ordinary knee table, a swivelling table is sometimes fitted. This swivels on a horizontal axis on the bracket slide, and can be fixed at any desired cant for angle drilling. The traverse of the spindle is 1 ft. 9¼ in. in a horizontal direction and 6 in. vertically. The table, which has a top 32 in. by 22 in. (or in the case of the swivelling table, 29 in. by 22 in.) has a vertical adjustment of 21 in. The greatest height between the table and the spindle is 2 ft. 6 in. The machine will drill up to 1 in. in mild steel and tap up to ¾ in. in cast-iron. The drive is designed for a pulley speed of 600 r.p.m.

Among the machines of the radial class shown by

Messrs. William Asquith, Limited, Halifax, are several of their well-known types as well as new models. One of this firm's new designs of radial drill is illustrated in Fig. 13, page 303. This is a belt-driven machine for moderately heavy work. As in all modern designs, the endeavour has been made to bring all controls within reach of the operator so that he may manipulate the necessary levers, &c., without withdrawing his attention seriously from his work. The spindle slide is carried on ball bearings, reducing the exertion required to move it along the radial arm. The sleeve carrying the arm is fitted with ball and roller bearings, and is very easily rotated. The machine embodies various interesting features. For instance, the belt drive is arranged so that clutches are rendered unnecessary. Three pulleys are employed, the two outer being fast pulleys, the central one being loose. One of the fast pulleys is keyed to a shaft and the other to a sleeve on this shaft. They drive respectively two bevels of a nest of three in the base of the column, the third bevel being mounted on the main vertical shaft. With this arrangement in combination with single gear on the saddle, the spindle is driven at any of nine speeds in the correct direction for drilling, &c., by one pulley. Other nine speeds in the same direction can be secured with the double gear on the saddle, with the other pulley, in which case quick reverse for withdrawal is obtained simply by changing from double to single gear. The backing-out speed in this case is 3·41 times the tapping speed.

Another interesting point about this machine is the position of the gear-box. Instead of being at about floor level near the foot of the column, the box is arranged on the radial arm in front of the sleeve. The change levers therefore, though not actually on the saddle, are on the same level as the saddle controls, and at a convenient height for the operator. Nine speed changes are provided by means of this box, and combined with the double gear on the saddle, already referred to, give 18 spindle speeds. The indicator plates give the correct speeds for drilling different sized holes. The spindle is placed as far back in the saddle as possible, so as to obtain a direct thrust. The feed change lever is located to the right of the saddle. The feed is by friction gear, which can be instantly engaged or disengaged, and is such that it enables the spindle to be adjusted finely though the feed is engaged. It can be engaged so lightly as to slip even when using small drills, if the drill should jam, thus reducing considerably the risk of breaking small drills. Four self-acting feeds can be used in conjunction with any of the spindle speeds.

The spindle is balanced by spring gear in the housing above. It has quick adjustment vertically, and the thrust is taken on double ball bearings. The radial arm is tubular with a long cylindrical sleeve fitting the column sleeve; the arm is raised or lowered by a lever near the base of the latter. The gears at the top of the column are only in motion when actually raising or lowering the arm. Trips are provided at both the upper and lower extremes to prevent over-running, and the elevating gear is also interlocked with the drilling mechanism. At the bottom right hand corner of the saddle is a lever which provides a triple lock simultaneously of the saddle on the radial arm, of the radial arm on the sleeve, and finally of the sleeve on the internal pillar, one movement of the operator effecting all three functions. Lubrication, it may be mentioned, has received a great deal of attention in this design, and as ball or self oiling bearings with oil baths are fitted, the operator has little trouble from this source. The oil troughs are fitted with sight gauges. No cup or Stauffer lubricators are employed.

Central thrust types of radial drills are also shown by Messrs. Asquith. In this design many of the features are similar to those described above, but the portion of the radial arm over which the saddle works consists of two walls, between which runs the spindle. The upward thrust on the arm is taken on large flat horizontal faces on the underside of the arm. These machines are furnished with quick power traverse, and a fine swinging movement to the arm, operated by hand. This can be engaged when required. Machines of this type are built in sizes up to 10-ft. radius.

An interesting machine designed as a portable radial unit is shown in Fig. 14, page 303. This is also by Messrs. William Asquith. It is independent, being electrically driven by a 3 h.p. constant-speed reversible electric motor mounted, as shown, on an extension of the radial arm. The drive is transmitted by belt to a gear-box at the back of the head. The gear changes provide for three speeds through sliding gears, combined with single or double gears in the head. The base consists of a bed mounted on rollers fitted with eight screw jack steadies. The column is carried on wide ways, the column saddle being provided with roller and ball bearings, and hand traversing gear. It can be locked in any position. The column carries a large sleeve which in turn carries the radial arm in a slide. The arm can be run in and out by hand or power. Hand and power elevating motions are also arranged in conjunction with the elevating screw shown to the right of the column. The arm will swing completely round the column the full 360 deg., while it may be tilted by hand motion through 30 deg. in a vertical plane.

The drilling head at the end of the radial arm can be swivelled to any angle and work can be done with the spindle at any angle. Thus any angular holes can be taken without packing the job. The drilling head is fitted with single and double gear. The single gear again gives, with the three change speeds, three speeds in one direction. The double gear and reversed motor gives other three speeds and for backing out quickly the double gear is thrown out and the single put into mesh. Both hand and self-acting feed are arranged for the spindle, the latter having two changes.

The machine is made for 4 ft. 9 in. and 5 ft. 9 in. radius and can readily be transported about a shop, a large eye being fitted in the column head for slinging from a crane. It will be evident that a machine of this type will present advantages for many special jobs on large works.

GRINDING MACHINES.

The variety of grinding machines at the exhibition is very large, but some of the well-known makers are not showing new models. We shall have occasion to deal with this class of machine at greater length subsequently; we now illustrate three new tools by the Lumsden Machine Company, Limited, Gateshead, whose selling agents, as is well known, are Messrs. Alfred Herbert, Limited, Coventry. The first machine illustrated in Figs. 15 and 16, Plate XXIX, is a large vertical grinder, of exceptionally robust design, using segmental wheels, 30 in. in diameter. The table of this machine is 72 in. long by 15 in. wide, and the maximum distance from table to face of grinding wheel is 15 in. As will be seen, the spindle is carried in a vertical ram mounted on a cross-rail which slides on the one side on a large cylindrical column, and on the other on a vertical column slide. A heavy horizontal housing connects the two columns at the top. The vertical adjustment of the cross-rail is 12 in. A belt-operated motion from the countershaft can be brought into gear to raise and lower the cross-rail by power. The ram is adjustable to the extent of 3 in. vertically on the cross-rail.

The table is carried on one vee and one flat slide, the drive being by rack and spiral gear, the spiral shaft being driven through reduction gears from a gear-box which gives two table speeds, viz., 8½ ft. and 13 ft. per minute. The automatic table reverse is actuated by dogs in T slots on the underside of the table.

The ram carrying the spindle is balanced by two coil springs in the cross-rail working on two cylindrical plungers attached to the ram. The spindle is driven by belt from a countershaft on the machine, over two jockey pulleys on the top housing. This countershaft is coupled direct to the gear-box. The grinding wheel can be fed to the work either by hand or by automatic gear, the minimum and maximum feeds for each reversal of the table being 0·0005 in. and 0·008 in. respectively. The spindle speed is 1,088 r.p.m. and the countershaft speed 725 r.p.m. The gear-box, countershaft, wheel spindle, worm shaft and loose pulleys are all fitted with ball bearings. The tension on the spindle driving belt can be adjusted by sliding one of the jockey pulleys on the cross-rail. The grinding wheel is 16 in. in diameter, made up of eight segmental blocks held by tapered dogs in the steel ring housing or chuck. The segments only protrude about ½ in. This type of chuck allows a wide latitude of choice in the grade of abrasive material used.

In Figs. 17 and 18, Plate XXIX, we give front and back views of a horizontal grinder, also by the same firm. This machine uses a 30-in. segmental wheel. The length of the table is 72 in. and its width 20 in.; the maximum table traverse is 7 ft. The maximum horse-power taken is 30; this is greatly reduced when strips or facings are being ground, instead of a full face. The maximum height from the table to the top of the wheel perimeter is 27 in.

The table, which slides on ways protected by fixed and flexible coverings, is driven at two speeds, viz., 7½ ft. and 15 ft. per minute, by rack and worm. The reverse is engaged by a spring-loaded dog clutch. Towards the end of the travel, while this spring is being loaded the clutch is held in gear. Consequently when released the reverse is quickly thrown in. The wheel spindle is carried by roller journal and ball thrust bearings in a large ram which slides in the main head. The adjustment of the ram, and so of the wheel to the work can be made from either side of the machine, with micrometer indicators to both hand or power feed. The spindle carries a chuck or steel ring housing in which the abrasive segments are wedged with only a small projection. The feed mechanism to the wheel ram embodies a relay arrangement in which friction gear on the worm spindle controls the tripping of a pawl by means of which the feed is operated positively. The feed can be varied from 0·0005 to 0·016 per reverse of table.

A profile machine is illustrated in Figs. 19 and 20. This is particularly intended for gauge and form tool grinding. It is also by the Lumsden Machine Company, Limited. At the back of the bed of this machine is a horizontal shaft on which is pivoted an oscillating arm or grinding wheel head. The wheel is mounted on the upper, free end of this arm, which also carries the profile follower or tracer, as may be seen in Fig. 19. By means of a hand wheel towards one end, on the front of the machine the shaft carrying the grinding wheel arm may be traversed to the extent of 12 in. Another smaller hand wheel, with a rim divided and indexed, allows fine lateral adjustment to be made of the work table. This wheel allows a total movement of the table of 1 in., each division on the wheel being equivalent to 0·0001 in. Further, the table is swivelled horizontally in front and can be tilted 10 deg. up or down so that various degrees of clearance can be ground. Of our two illustrations one shows the tool used for grinding external and internal snap gauges. For this work a double cup wheel is used. The blanks are bolted to the table with faces set parallel to the cross traverse of the wheel. The back shaft is then traversed to bring the wheel into position and locked, the fine micrometer feed being used to bring the work up to the wheel. The wheel is pulled forward by the long lever pointing upwards, and, after grinding, is forced back again clear of the work by a spring. A stop prevents the wheel being pulled over too far and into contact with the table. This stop is adjustable to allow for the use of smaller sized wheels.

For form tool work a plain wheel is used, as shown in Fig. 20, Plate XXIX. The former is bolted to the table and a tracer provided with coarse and fine adjustment is mounted on the end of the grinding wheel arm. The lever of the wheel arm is pulled forward so that the tracer bears up against the profile, and the wheel is then traversed by means of the hand wheel, across the face of the work. The feed is adjusted by the knurled screw on the tracer fitting. This can be screwed in and out to allow the wheel to move in towards the table, or keep it further off as required. Form tools of the type shown mounted on the table are ground ready for hardening in less than five minutes, after being roughly milled to shape. The tracer, of course, had to have a radius smaller than or equal to the smallest of the profile, in order to reproduce the form accurately. The machine has a table 27 in. long by 8 in. wide. The grinding wheels are 10 in. in diam. and run at 2,100 r.p.m. The wheel arm will swing 4 in. The wheel spindle, it may be

remarked, is fitted with ball bearings, and the drive to the swinging head is by belt from a ball-bearing countershaft in the base of the machine. The countershaft speed is 700 r.p.m.

VERTICAL BORING AND TURNING MILLS.

There are at the exhibition many examples of boring and turning mills, mostly associated with the names of well-known firms. Messrs. Alfred Herbert show one of the standard Bullard machines, which, it must be admitted, did much to bring to the fore this now popular class of machine tool. In Figs. 21 to 24, Plate XXX, we illustrate four typical modern examples of British machines, and it will be noticed that compared with previous models the capabilities of this tool are gradually being enhanced, while at the same time much has been done to simplify the control. The two duplex mills are respectively shown by Messrs. Webster and Bennett, Limited, Coventry, and the Atlas Engineering Company, Leeds. The latter firm is showing a 20-in. duplex boring mill by Messrs. G. Wilkinson and Son, of Keighley. This machine, illustrated in Fig. 21, Plate XXX, is an excellent example of modern British tools of this class. The size illustrated takes work 22 in. in diameter. The height admissible under the turret saddle is 15½ in., and under the turret 22 in. The turret has a vertical feed of 16 in. The machine is driven by electric motor and belt pulley to a fast and loose pulley on the side of the machine near the floor. The shaft on which these pulleys are mounted is carried in a housing forming part of the speed-gear change box. Eight table speeds are provided. The feed and traverse movements are obtained by a cone pulley drive of two steps, from a short spindle run by the main belt drive, up to shafts at the back of the cross-slide. Here a gear-box provides, with the two stepped cone pulleys, for six speeds of feed. The machine has hand or automatic traverse to the slides, and both feeds and traverse are changeable and reversible while the machine is in motion. Feed and traverse trips and index dials are fitted in the housings at either end of the cross-slide. The turret slide can swivel on main slides, and the angular feed can be controlled similarly to the vertical. It may be mentioned that the tables spindles are carried in large conical bearings, the thrust being taken on large ball bearings. The tables are driven by spur gearing which eliminates any tendency to lift. The turrets and slides are counterbalanced by cross chains, shown above the main cross slide. Each turret is suspended by a chain running over a small pulley, on the same spindle as a larger pulley to which is also attached a chain, at the other end of which is a weight. This is a self contained arrangement, each weight being suspended inside one of the back frame columns. The horse power per table is stated to be 5. The turrets are canted so that tools do not interfere with each other.

Another representative British duplex mill is that illustrated in Fig. 23, Plate XXX. This is by Messrs. Webster and Bennett, Limited, who have a well deserved reputation for this class of tool. The firm is showing, in addition to the 42-in. mill illustrated, a 20-in. duplex mill and a single 30-in. mill. These machines are similar in character. The duplex mill consists of a right and a left-hand unit. The base of the machine is in one casting, but the columns are independent, bolted to the base and joined by a panel plate. The cross-slides are also separate for each mill and are joined by a bridge-piece at the back. The machine is driven by belt on to a single pulley at the back; all motions are derived from this spindle. It is controlled completely from the front. The main clutch for the right-hand mill is operated by a lever shown at the near corner of the machine in our view; the table speeds are all controlled from the same point. The 42-in. mill has 12 speeds obtained by combinations of three levers. The 20-in. mill has 12 speeds, obtained with two levers, one of four positions and the other with three. The lever for the feed control can be reached by the operator from the same position. This lever has four movements, up and down and sideways. By its means the feed can be thrown out and rapid or slow traverse thrown in instantaneously so that the slide can be rapidly controlled. The rapid traverse is obtained by belt drive from the main pulley spindle to a spindle at the back of the slide. The nine feed changes are obtained by a gear-box operated by levers in the same way as the speed changes are worked. This box may be seen at the side of the base below the column. The feed and traverse cannot be engaged simultaneously as both obtain their drive through a spur on a rocking lever, which can engage only with one or the other. A handy form of trip gear is arranged for both feed and traverse. Towards the end of the slide will be seen two small discs with milled edges. These discs are graduated in inches and fractions and can be easily turned by hand. If a certain feed or traverse is required the proper disc is turned till the mark for the required distance is opposite a pointer, and when the part has moved this amount the feed or traverse, as the case may be, is tripped. In addition, a safety catch prevents over-running. The left-hand table is provided with a reverse so that right-hand tools may be used and the actual cutting operation on this table brought under good observation within reach of all the controls, which on this side of the mill are of course on the operator's left hand.

The turret head is counterbalanced by spring and fusee. It will be noticed at the exhibition that there is a well-marked tendency to adopt some compact gear of this type in place of the former counterbalance weight which is often difficult to arrange conveniently. This applies to various types of machines other than these mills, as for instance, radial and other drills. The Webster and Bennett turrets take five tools, and in the 42-in. machine the turret is revolved by two levers and clamped by a third. It may be mentioned that the turret tool sockets, 3 in. in diameter, are bored in position in the machine, by a drill held in the jaws of the table, thus ensuring perfect alignment. The horizontal feed of the turret slide on the cross-slide from the centre outwards is 24 in., and the vertical feed 26 in. The machine will admit work 46 in. in diameter, while the admissible height under the turrets is 31 in. and under the cross-slide 21 in. The turret bars can be canted if necessary, a large indexed sector insuring accurate setting. This is done by unclamping the slide, fixing a draw-bar over pegs to be seen on the upper ends of the slide, and then traversing the other head, pulling or pushing over the head to be swivelled. This machine is stated to take 8 h.p. per table.

Messrs. Cunliffe and Croom, Limited, Broughton Iron Works, Manchester, are showing two mills of different types. One is a single 30-in. mill of the type with fixed cross-slide, while the other is a large 51-in. mill with adjustable cross-slide. The former machine is very simple. It has a belt drive from a two-speed countershaft to four step cone pulley, with four cone pulley drives up to the feed. The table drive is fitted with gearing so that 16 speeds may be obtained. Twelve changes of horizontal traverse, and eight changes for vertical and angular feed are also arranged so that the machine will work over a very wide range. The slide is counterbalanced by chain and weight. The turret slide is arranged to swivel. The turret is circular and will take five tools. The larger machine is, as already mentioned, of the type with adjustable cross-slide. It is belt-driven, with a gear-box giving 18 changes of speed to the table. The cross-slide is raised and lowered by power. Two heads are provided, one for boring and the other fitted with a large swivelling turret for five tools. The feed-change box provides eight changes. Automatic trips prevent over-running. The feed to each head is independent. The heads are counterbalanced by chain and weight.

Of a similar class are the two machines we illustrate in Figs. 22 and 24, Plate XXX, by Messrs. John Stirk and Sons, Limited, Halifax, and Messrs. George Richards and Co., Limited, Broadheath, Manchester. The former (Fig. 22) is a single table, 42-in. machine fitted with two boring bars, though, as is often done, these machines may be fitted with one boring bar and one vertical turret head. The machine is driven by a Crompton variable-speed 7½-h.p. motor and controlled by automatic switch gear by Messrs. Brook, Hirst, and Co. The table speeds thus obtained range from 1·6 r.p.m. to 52·5 r.p.m., while the feeds are arranged in nine steps, from 32 to 2·6 cuts per inch. The cross-slide is raised and lowered by power by enclosed screws and worms. Each head carries a long tool bar which can be swivelled to 45 deg. either side of the vertical, by means of a worm and segment, which is indexed. This arrangement is plainly visible on the near head in Fig. 24. The feed and traverse motion is transmitted to the slide by sliding gears on a vertical shaft from the feed-change box. The feed boxes are independent and reversing for each head, and all the required safety tripping arrangements are provided. Quick and fine hand adjustments to each tool post are also included. The table is worm-driven with multiple thread, and the table thrust is taken on a large ball bearing. The heads are counterbalanced by a single chain and weight. This machine admits under the cross-slide work of a height of 30 in., and under the toolholder 24 in.

The firm of Messrs. George Richards was one of the earliest firms to take up the manufacture of vertical mills in this country. Their latest designs are exemplified by the machine shown in Fig. 24, Plate XXX. This is a 48-in. boring and turning mill, with a single table and two tool posts though, as illustrated, the machine is fitted with one tool post and one turret. Either can be supplied, according to the nature of the work. This machine is also driven by a direct-current variable speed motor. It is of 13 h.p. and is by the Lancashire Dynamo and Motor Company, Limited, Manchester, the controller gear being by Messrs. Brook, Hirst and Co., Limited, Chester. The cross-rail is raised and lowered by power. The rates of feed, in 12 changes, independent and reversible, range from $\frac{1}{17}$ in. to ¾ in. The heads have rapid power traverse horizontally and vertically. They are balanced by spring gear. At either end of the cross-rail there is a friction slipping arrangement to prevent damage to the feed gears in case the heads collide accidentally. The tool posts can be swivelled by a worm and segment. The maximum height under the cross-slide is 35 in., and under the tool post 29 in. The tool posts have a vertical feed of 20 in. The table is 44 in. in diameter.

HORIZONTAL BORING MACHINES.

Horizontal boring machines, of course, take various forms according to the class of work they are used on. What has become known as the horizontal boring, drilling, tapping and milling machine is a tool of a very wide range of service. There are several at the exhibition of a more or less uniform type, but differing considerably in features of design. In some of these machines every combination has been included to make them as near "universal" as possible and they would probably find their way into more shops if their capabilities were rightly appreciated.

Two horizontal boring, milling and drilling machines are exhibited by Messrs. Cunliffe and Croom, Limited, Manchester. One of these is illustrated in Fig. 25, Plate XXX. The drive of this machine is by constant speed belt to a gear-box giving eight spindle speeds. The spindle traverse is 24 in. and the maximum height from spindle to table is 2 ft. 8 in. The distance from faceplate to outer support is 5 ft. The table will lock in four positions of adjustment. It has power feed in all directions and a traverse of 2 ft. 6 in. by 2 ft. 6 in. Vertical power feed and adjustment upon the column is arranged. Indicator scales are fitted to all adjustments. The boring head is balanced by chain and weight, and the drives are transmitted through vertical spindles with gears fitted with sliding keys.

Excellent examples of this class of tool are shown by the Atlas Engineering Company, Leeds, who are exhibiting two horizontal, boring, drilling, tapping and milling machines by the Dickinson Machine Tool Company, Limited, of Keighley. The larger machine, a 3½-in. size, is illustrated in Figs. 26, Plate XXX. This machine is driven by belt to a single pulley gear-box fitted with a Johnson clutch. This box gives 18 spindle speeds, ranging from 7 r.p.m. to 200 r.p.m., all reversible. The spindle saddle is carried by a vertical column of box section open through the middle. The thrust is thus

taken centrally on two wide front faces. This is a very sound type of design of column. The spindle drive is by a vertical shaft, seen to the left of the column, which transmits the drive, by a horizontal shaft carried in the saddle, to a spur on the front of the saddle encased just over the boring spindle. This spur drives a corresponding wheel through which the spindle slides, the spindle drive thus being as close as possible up to the tool. The feed, from the feed-change box, is taken by a vertical spindle to a horizontal one, and thence to the worm and pinion carried by the saddle extension to the left of the column. The spindle has vertical feeds for milling, and rapid power movements in all directions. The spindle has nine feeds, also reversible, equivalent to from 0·007 in. to 0·134 in. per revolution of spindle. The spindle longitudinal traverse is 24 in., equivalent to 48 in. at two settings. It has a vertical traverse of 21 in. The feed changes to the spindle saddle, to the outer stay in which the bearing moves with the main spindle, the table, and the table saddle, are in every case nine in number and reversible. In addition, hand movements are fitted throughout. Quick power traverse is also fitted to the spindle traverse, outer stay, table and table saddle. All feeds are interlocked, and a safety slipping device is introduced to prevent breakage of gears. A graduated scale is fitted to the column. The saddle is balanced by chain and weights.

The main table is 28 in. by 45 in., on which there is a revolving table 28 in. by 28 in. The table has a cross-traverse of 30 in. and longitudinal movement of 51 in. The revolving table has a rotary motion with checks so that work can be machined on four sides at one setting. A self-lifting device is fitted to the top table to facilitate rapid rotation by hand. The maximum height from the revolving table top to the main spindle is 24½ in. The maximum distance from the facing head to the outer stay is 7 ft. The horse-power required for this machine is said to be 9.

Our illustration, Fig. 26, shows the new Dickinson facing head fitted to the 3½-in. machine. This head makes it possible to face from the maximum diameter to the centre and then to reverse and face outwards, and in again automatically, while the feed can be tripped at any point on the surface of the work. The spindle can be run at one speed, and the facing head if desired at another. The head can be stopped when the spindle is running at high speed for drilling. Similarly the boring spindle can be stopped while the facing head is revolving. The facing head can be run in either direction. The feed-change gear-box gives nine facing speeds.

The other two machines of this class which we illustrate this week are both of well-known makes. The first is a Pearn-Richards machine which is illustrated in Fig. 39, annexed. This machine, made by Messrs. George Richards and Co., Limited, Broadheath, is at the exhibition, driven by a 6-h.p. constant speed direct-current motor, and the gear arrangements provided enable the speed of the spindle to be run at 32 changes, ranging from 3·8 r.p.m. to 200 r.p.m., thus giving an exceptionally wide range of work from milling and boring to high-speed drilling, &c. There are eight reversible feeds to the spindle, and eight feeds are also provided for the vertical traverse of the spindle, as well as for the longitudinal and transverse movement of the table. Rapid power traverse is also given for these movements. The automatic table traverse is 42 in. in a longitudinal direction, and 32 in. crosswise. The spindle has a range of from 4 in. to 23 in. above the top table and from 8 in. to 27 in. above the main table. The maximum distance from the facing head to the outer stay is 5 ft. 5 in.

The remaining machine of this type which we shall deal with this week is an excellent example of the work of Messrs. H. W. Kearns and Co., Limited, of Broadheath, Manchester. This is illustrated in Figs. 50 to 53, page 316. Messrs. Kearns make two models in various sizes; one is known as their "standard" machine and the other as "Kearns' patent" machine, both of which are exhibited. It is the latter which we illustrate this week, the example at the exhibition being a No. 2 size, driven by a 5-h.p. electric motor. Like the machine just described above, Messrs. Kearns adopt a belt drive for the spindle, running over a jockey pulley to take up the belt when the head is adjusted vertically. Our illustration, Figs. 52 & 53, show a belt drive to the main pulley; apart from this the drawings are substantially of the machine at the exhibition. The drive is arranged with a clutch which is included with the gears in a box at the back of the machine. With the clutch lever, all gear changes, eight in number, are obtained by a single gate lever, at the front of the machine. Each of these changes can be used direct, or in single gear, or double gear, giving 24 speeds in all to the spindle. These range from 3·1 r.p.m. to 250 r.p.m. When drilling or boring small diameters direct drive is used without the intervention of gearing. The spindle revolves with or independently of the facing head so that boring and facing may be conducted simultaneously or independently. The feed changes in either direction are obtained from a change box at the left-hand end of the base. This box gives eight changes, ranging from 8 to 96 cuts per inch. These feeds are to the facing slide, vertical spindle traverse and longitudinal and transverse traverses. The spindle has a longitudinal traverse of 24 in., or at two settings of the work will cover 48 in. The spindle is provided with an extension bracket in which the feed worm is arranged. Quick hand adjustment is provided for the spindle and all other motions. The large hand wheel in front is for adjusting the table and head, clutches being thrown in for the hand motions by levers near by. The large lever in front is the main clutch lever. A treadle brake is fitted to bring the machine to rest.

The machine is shown fitted with a facing head which obtains its feed from the main feed-box. This feed is carried to the head through epicyclic gears giving eight feeds in either direction to the cutter on the head. These feeds range from $\frac{1}{16}$ in. to $\frac{1}{2}$ in. per revolution of spindle. The maximum diameter this machine will face is 30 in.

The spindle has a vertical traverse of 18 in. with a maximum distance from the centre to the main table of 26 in. The main table is 48 in. by 30 in., and the top table 36 in. by 36 in. The longitudinal traverse of the main table is 42 in. and transverse is 37 in. The detachable table can be locked at any angle, and is fitted with a setting stop for four 90-deg. positions. A centring pin can be used to ensure true positioning in relation to the spindle. Messrs. Kearns have introduced a locking and squaring device in which these operations are achieved by two pinions acting on special H-pieces which slide into the T-slots of the lower table and corresponding T-slots on the underneath of the upper table.

The view, Fig. 50, shows a test-piece on the table ready for testing the accuracy of the machine. The machines are put through six tests in which the limits allowed are as follows: (1) Facing flat surface limit 0·0005 in., flanges to be parallel to 0·002 in.; (2) outside and inside flanges of test-piece to be concentric when bored with tools 12 in. apart to 0·001 in.; (3) the same test with tools 30 in. apart, limit 0·001 in.; (4) bore to be continuous in double setting, limit 0·001 in.; (5) milled faces to be parallel to 0·001 in.; (6) milled cuts to be parallel with faced flange and milled webs to be square with cut on flange, limit 0·001 in.

THE MACHINE TOOL AND ENGINEERING EXHIBITION.

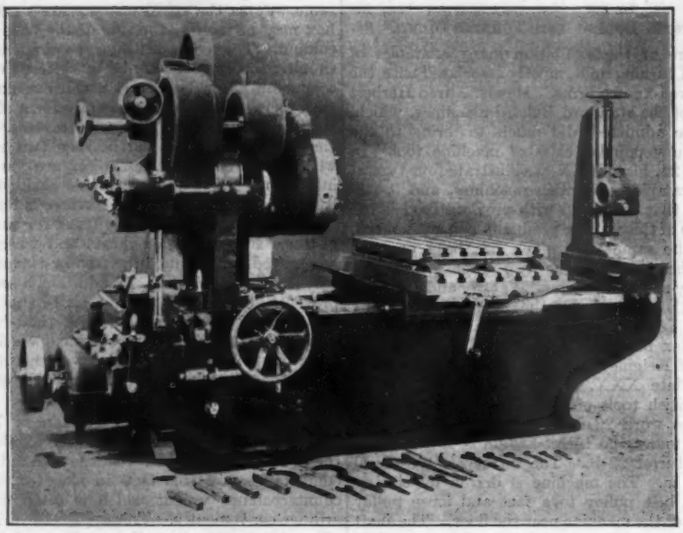


FIG. 39.—PEARNS-RICHARDS HORIZONTAL BORING MACHINE; MESSRS. GEORGE RICHARDS AND CO., LTD.

LATHES.

Quite naturally lathes form a predominant feature of the exhibition, and we cannot attempt to deal with all the models shown. We have therefore selected certain machines for illustration this week, and shall hope later to deal with other tools of this class possessing special features of interest.

The usual neatness of design which characterises the tools made by Messrs. Drummond Brothers, Limited, Guildford, is well exemplified in a new model this firm has just brought out of 3½-in. lathes. This little tool, with attachments, can be made to do an enormous variety of work, but at the moment we intend to confine ourselves to a description of the lathe itself, which we illustrate in Figs. 27 to 38, on Plate XXXI. The general view shows this small lathe to be at once neatly and substantially built. This is borne out by an inspection of the details and drawings of the bed, the latter being shown in Figs. 34 to 38. The bed is of box section, and is self-contained, ensuring accuracy wherever placed. Distortion due to a bad floor is not transmitted to the body of the lathe proper. The sections of the bed, and the details we give of the head and tail stocks are interesting. The front shear gives a 90-deg. saddle guide, while the back one is given clearance on the back side. The saddle is held to the back of the front shear by a gib, and tipping strains are taken by the back shear by means of a stiff gib sliding underneath. The lead screw is brought right into the bed, close under the saddle, thus reducing the couple on the saddle as much as possible.

The headstock is illustrated in Figs 30 to 33. It is permanently clamped against the front vertical face of the back shear. The headstock base takes the form of a beam of great rigidity for the size of the machine. The spindle is hollow, and is fitted with ball thrust bearings. The adjustable bronze bearings are long and widely spaced. The back gear works on eccentrics, with bronze bushes. The spindle and cone lock is illustrated in our figures. The cone pulley is disengaged from the gear wheel keyed to the spindle when the back gear is required,

THE MACHINE TOOL AND ENGINEERING EXHIBITION.

FIG. 40. No. 4. CAPSTAN LATHE; MESSRS. ALFRED HERBERT, LIMITED.

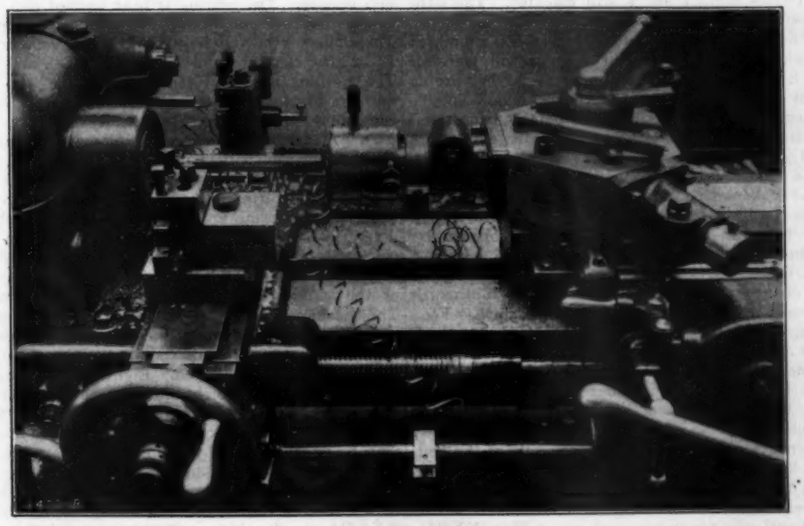


FIG. 41. CAPSTAN LATHE ARRANGED FOR MACHINING BOILER STAYS.

by pushing a knurled knob, working in a slot on the mandrel gear front face, up an incline. This action withdraws from the boss of the cone pulley an accurately fitting pin, thus releasing the cone from the spindle. To re-engage for the direct drive the knob is started at the top of the cam or incline, and the action of a spring automatically returns it to its locked and driving position. No spanner is required for the operation. The tailstock is illustrated in Figs. 28 to 29. It has set over adjustment for long taper work, with graduated scale. It is guided like the saddle. The lock is by means of a lever and spindle working eccentrics which simultaneously draw in the gibs under the front and back shears. This is a very effective method.

The lead screw is cut on a machine fitted with pitch-correcting gear. At its right-hand end it is carried in a bronze bushed bearing. At the left-hand end it is fitted with a clutch. It also has automatic throw-out gear which can be operated at any position along the bed. The screw-cutting gear studs, and lead-screw end, are fitted with spring plug retainers. To remove the gears, the retainer is simply pulled out by its head and the wheels can be at once changed without the use of a spanner. The change-gear quadrant has a second quadrant as an extension to the back, which is provided with a clamp and nut. The slide rest is compound, the top slide being fitted with a graduated base.

The lathe is fitted on a stand for self-contained electric motor drive, and for belt, or for treadle, in the latter case a ball bearing flywheel and treadle link being fitted. As already mentioned, a number of attachments are designed for this tool, as for instance, a milling, indexing and gear-cutting attachment, grinding attachment, a turret attachment, and so on. The latter carries five tools. It fits on to the boring table on the lathe saddle. The maximum distance between the faceplate and turret face is 1 ft. 2 in., and the turret longitudinal traverse is also 1 ft. 2 in.

There are naturally many capstan lathes on exhibition and of them we are this week illustrating some examples. The first on our list is such a well-known machine as perhaps hardly to require description, although on the other hand it may be said to have taken such an important place in the workshops of the country that it is impossible to ignore it when dealing with the Olympia display. The lathe referred to is the No. 4 capstan, built by Messrs. Alfred Herbert, Limited, of Coventry. It is illustrated in Figs. 40 and 41, annexed. The latter of these figures shows the lathe as set up for machining locomotive boiler stays, and in view of the fact that the main features of this lathe are generally known, we may perhaps usefully base our reference rather on a description of this machining operation than on a description of the lathe itself. For manufacturing locomotive boiler stays in large quantities a full automatic may no doubt usefully be installed, but in many cases, and particularly for repair work, the machining may very well be carried out on a capstan lathe. The attachments shown in Fig. 41 have been specially got out by Messrs. Herbert for this work.

The stays are manufactured from copper bar stock, drawn about 0·01 in. over nominal size. It is gripped in the draw-in chuck of the lathe and on the first capstan face there is an adjustable stop against which the bar feeds and which regulates the length of feed in the usual way. The second capstan face carries a holder fitted with a cast-iron sleeve bored an easy fit on the bar and this supports the end of the stay, while a tool on the back of the cross-slide is fed into the depth of the clearance portion. On engaging the automatic feed to the

capstan slide, a boss on the sleeve holder pushes the slide along. The clearance portion of the stay is thus traverse turned. Threading is the next operation, and this is carried out by a Coventry self-opening diehead. Owing to the gap between the two ends of the stay it is obviously necessary to provide some means of maintaining the two threaded ends in continuous pitch. This is accomplished by coupling the diehead up to the chasing saddle. A notched hardened steel collar is fixed at the rear of the diehead and on the front of the cross slide there is a block carrying a plunger designed to engage the notch. The diehead is brought up into position at the end of the stay and the cross slide moves along until the plunger is a little to the right of the notch. On engaging the chasing mechanism the cross slide moves inward in the usual manner, thus compressing the plunger, and the chasing saddle commences to move. When the plunger is opposite the notch it snaps in and carries diehead and capstan slide along at the correct pitch. Immediately the diehead reaches the end of the first threaded portion of the stay the friction clutch in the headstock is thrown over by hand on to the fast speed, so that the gap is rapidly traversed. The speed is then again changed on to the slow speed, for the second threaded end.

The chasing saddle is automatically brought to rest at the end of the second threading, thus preventing any danger of over-running and the diehead then pulls off and opens. On disengaging the chasing mechanism the saddle moves outward, releasing the plunger from the notch and permitting the turret to be withdrawn. This leaves the cutting-off tool in position for parting-off the stay. This lay-out enables copper stays 1 in. in diameter by 7 in. long to be machined in 65 seconds. Similar stays from reeled mild-steel bar can be produced in 2½ minutes. The standard attachment carries a 1-in. diehead and threads stays up to 1 3/4 in. diameter and up to 9 in. long. A 1½-in. diehead may be fitted for dealing with stays up to 1⅞ in. diameter, but in this case it is necessary to provide a vertical slide on which the diehead can be raised by hand when swinging, otherwise the diehead would foul the turret slide.

Two capstan lathes exhibited by Messrs. H. W. Ward and Co., Limited, of Lionel-street, Birmingham, a firm whose name is specially connected with this type of machine, are shown in Figs. 43 and 44, on Plate XXXII. The former of these figures shows the firm's 7-in. all-geared capstan and the latter their 6½-in. friction-geared capstan. The all-geared headstocks of all the lathes manufactured by Messrs. Ward have heat-treated steel gears, all sliding wheels being carried on castellated shafts. The clutch is of the cone, metal-to-metal type, spring-loaded, and the declutching movement is inter-connected with a brake acting on the first shaft and capable of bringing the spindle rapidly to rest. This permits of quick changes of speed. The 7-in. all-geared lathe shown in Fig. 44 is an entirely new model and contains, we think, more motions than previous machines built by the firm. The spindle is bored 2⅛ in. diameter and has eight speeds in either direction. The saddle has automatic sliding surfacing and screw-cutting motions, with stops to all movements. The screw-cutting motion is obtained from a leader driving from a quick-change gear-box totally enclosed in the bed of the lathe. The capstan rest has 10 automatic feeds independent of the chasing saddle. The 6½-in. friction-geared lathe is capable of dealing with bar work up to 2 in. diameter and chuck work up to 6 in. diameter by 8 in. long. The headstock is of the friction-geared type and can be put in and out of gear while the machine is running. The saddle has the usual hand motions and gear drive from a four-change box. Two leaders are furnished with each machine. The capstan rest has six changes of feed.

Some interesting lathes are shown by Messrs. Thomas Ryder and Son, Limited, of Turner Bridge Works, Bolton, from among which we would first refer to a very neat 7½-in. hollow-spindle, sliding surfacing and screw-cutting machine, which is illustrated in Fig. 45, on Plate XXXII. The lathe is of the all-geared-head type in line with Messrs. Ryder's other models, the firm having entirely abandoned the old stepped cone form of machine.

THE MACHINE TOOL AND ENGINEERING EXHIBITION.

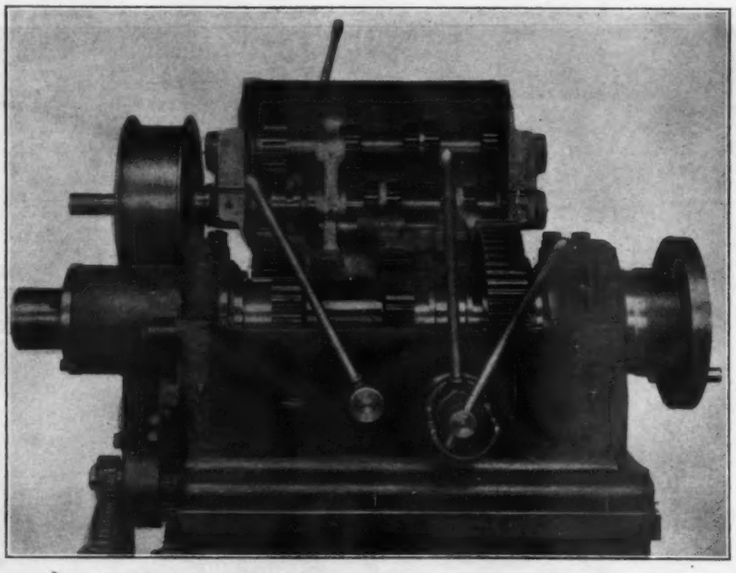


FIG. 42. SPEED GEARS OF 10-IN. LATHE; MESSRS. GEO. SWIFT AND SONS, LIMITED.

It will be clear from the figure that in the design a powerful type of lathe for its size has been aimed at. High output is, of course, helped by the all geared head since there is less inclination on the part of the operator to run at too low a speed during part of the turning of an article rather than take the trouble to change the position of a belt running on stepped cones. The form of bed and standard also gives rigidity and a stiff machine. The lathe is built in one size only with a bed 7 ft. 6 in. long.

The fast and loose pulleys run at 350 r.p.m., at which speed the belt and gearing will transmit 2½ h.p. There are eight spindle speeds varying from 20 r.p.m. to 260 r.p.m. The hollow spindle bearings are of Messrs. Ryder's patented form and consist of a cone bearing at the front end and a ball journal at the rear end. The thrust is taken by a ball-thrust washer mounted against the main headstock casting inside the cheek. The forward cone bearing is in the form of a bush, and to adjust for wear the bush is moved slightly forward by means of nuts. This adjustment leaves both the spindle and the thrust washer stationary. There are 18 changes of feed for 18 standard Whitworth threads, from 4 to 28 threads per inch. Feed change is obtained by a sliding gear feed-box which also contains the reversing mechanism. The guide screw is located endwise by ball-thrust washers. The lathe can be supplied to cut metric pitches only if desired. The design allows of direct driving by electric motor if required, the motor being fixed on an extension fitted to the back side of the bed. A 2-h.p. constant-speed motor is recommended.

We illustrate on Plate XXXIII a larger Ryder lathe, but before passing to it we would like to deal with the remaining machine, on Plate XXXII, as this has some affinity with the capstans to which we have already referred. As we have already pointed out it is not possible in this first notice to deal with the lathes in rigid groups, but at the same time it is desirable to deal, as far as possible, with the heavier and lighter machines, independently. Fig. 46, on Plate XXXII, shows a 5½-in. capstan lathe built by Messrs. Pollock and Macnab (1919), Limited, of Bredbury, near Stockport. We should say that the makers describe this as an 11-in. swing lathe, but it has appeared desirable to retain the English practice of stating the size of a lathe by the height of the centre. The definition in terms of swing is, we think, of American origin, and we do not know that it has any advantage over the older system. In any case the use of the two methods side by side is apt to lead to confusion.

This Pollock and Macnab 5½-in. capstan is a powerful machine for its class, and will easily cut a 1-in. Whitworth thread in steel at one cut. Its general appearance is well shown in Fig. 46. It is suitable for bar or chuck work, and having an all-geared head is capable of doing work which is frequently allotted to a more expensive type of machine. The headstock gives four speeds forward and reverse. The gearing is heat treated and the shafts are castellated and run in ball bearings. The diameter of the hole through the spindle is 1⅝ in., the chasing saddle feeds are 24, 48 and 96. The working stroke of the capstan slide is 6 in. and the feeds are 48, 80 and 160. The hexagonal capstan is bored through to permit long bars to pass. A further machine exhibited by Messrs. Pollock and Macnab is illustrated in Fig. 47, on Plate XXXIII. This is the firm's new model 8-in. combination turret lathe. The headstock gives eight speeds forward and reverse and the particulars given in reference to headstock construction in connection with the 5½-in. capstan apply equally to this model. The bar centring chuck at the rear end of the spindle is adjusted by means of a scroll. The chasing saddle has eight sliding and cross-feeds and the automatic trips and stops have independent adjustment. The square tool post does not rise from its base when rotated. Eight leader changes are provided enabling eight pitches to be cut with one leader and nut. Sixteen feeds are provided for the turret slide, and a quick power traverse. The turret may be rotated either by hand or by an automatic motion.

Of the two remaining machines we have to deal with this week the first, shown in Fig. 48, on Plate XXXIII, is the 13-in. all-geared gap lathe by Messrs. Ryder and Son. Some of the constructional features of this machine we have already indicated when dealing with the firm's 7½-in. hollow-spindle lathe. The 13-in. lathe appears an admirable and powerful general purpose tool. The driving pulley runs at 450 r.p.m. and will transmit 11 h.p. There are 12 spindle speeds, from 6 r.p.m. to 127 r.p.m.

Another powerful lathe, by Messrs. George Swift and Sons, Limited, of Claremont Ironworks, Halifax, is illustrated in Fig. 49, on Plate XXXIII, while the headstock gears are shown in Fig. 42, on the present page. This machine is driven by a 15-h.p. constant-speed motor through a raw-hide pinion. A friction drive between the motor and gear-box allows of gear changes being made without stopping the motor. There are 16 spindle speeds controlled by three levers and it is impossible to engage conflicting sets of gear. There are six changes of feed

driven from a gear-box of the sliding wheel type. A double-walled apron fitted to the saddle carries a drop worm for engaging the feeds. The lathe admits 6 ft. 6 in. between the centres, and the height over to saddle is 7¼ in. A job 37½ in. diameter by 10½ in. long can be dealt with in the gap. Referring to Fig. 42, it may be said that the sliding wheels on the first and second shafts are of mild steel case-hardened, and that oil ring bearings are fitted to the front and back necks. The reverse motion is enclosed at the end of the head in a bracket which is also fitted with a large thrust washer. The gearing runs in oil.

(To be continued.)

INDUSTRIAL NOTES.

THE ballot of the miners throughout the United Kingdom showed the following figures:—

In favour of a strike	606,782
Against	238,865
Majority in favour ...	367,917

It should be noted that the juvenile workers in the coal-mining industry are reported to number 19 per cent. under 21 years of age, 14 per cent. under 18 and 7 per cent. under 16, many of whom, presumably, voted in favour of a strike. On Tuesday a meeting was held of the Executive of the Miners' Federation with representatives of the Transport Unions, when the following resolution was passed:—"That this conference of the constituent bodies of the Triple Alliance having heard the statement of the miners' case for the reduction in the price of domestic coal by 14*s.* 2*d.* per ton and for an advance of wages of 2*s.*, 1*s.*, and 9*d.* per shift for adults, youths, and boys respectively, are unanimously of opinion that the claims are both reasonable and just, and should be conceded forthwith." Another meeting of the Triple Alliance was held on Wednesday at which "the miners' position was further considered, the meeting deciding to authorise the Sub-Committee of the Alliance to remain in continuous session, with power to add to their number, and to convene a further meeting of the full body as circumstances may direct, after the policy of the miners has been finally declared at their own conference." It is worthy of note that only moral support is suggested in the resolutions.

The executive of the Miners' Federation met on Thursday and decided that strike notices should be given to take effect not later than the 25th inst. Meanwhile labour is trying to settle the issue by a compromise; but so far the Government is firm.

Mr. Seymour Berry, speaking at the ordinary general meeting of the shareholders of Guest, Keen and Nettlefolds, Limited, on Thursday, August 26, said he came from the district of Merthyr Tydfil, and he took a great deal of interest in the relationship which existed between Capital and Labour in that district. He took the opportunity of the meeting to reply to a remark which had been made by one of the extreme leaders of working men during the preceding week in reference to the profits of the company. Working out the profit per ton of the coal trade, so far as the company was concerned, and having regard to the Coal Mines Act, the retainable profits last year which the company had on all their collieries was not more than 6*d.* per ton.

The manager of the Stanton Ironworks, Notts., has stated that in the case of a strike the immediate closing down of his works and the throwing out of thousands of workmen would follow. He added: "We are sick of damping down furnaces during the last two years. If they go out now we will relight them at our own convenience."

In our last issue, we referred to the dispute at the Penistone works of Messrs. Cammell Laird and Co., and stated that the situation might lead to a lock-out. Last Friday or Saturday the following notice was issued to a number of works at Sheffield and district: "The members of the Electrical Trades Union employed by Messrs. Cammell Laird and Co., Limited, Penistone, having struck work against the employment of a foreman because he is not a member of the Electrical Trades Union, and the union having endorsed their action, the Federation, whilst regretting the unemployment of other workpeople which will necessarily result, have resolved that until the Electrical Trades Union admit the right of employers to employ foremen without regard to whether they are union or non-union, federated firms should discontinue the employment of members of the Electrical Trades Union. Notice is accordingly hereby given that on September 4 the services of the members of the Electrical Trades Union employed in these works will be dispensed with." Conferences have taken place which point to the fact that the General Workers, Iron and Steel Trades Confederation, and Amalgamated Engineering Union are at variance with the Electrical Trades Union.

Newspapers ceased to appear in Manchester and Liverpool as from last Monday, the members of the branches in those two cities of the Typographical Association having decided to go on strike without notice last Saturday. As stated in several of our former issues, the point in dispute is the granting to the employees of an advance of 10*s.* in wages instead of the 20*s.* which had been demanded, the matter being complicated by a question of overtime. In connection with the strike, the following statement has been made by Mr. A. E. Goodwin, secretary of the Federation of Master Printers: "The action which it is stated the members of the Manchester and Liverpool branches are taking is in direct contravention of the undertaking given by the National Executive, with the full knowledge and consent of the branches, that no embargo on overtime should be imposed without a fortnight's notice. In view of the fact that the conference which is to review the whole position and take into consideration the claims of the entire membership of the Typographical Association has been fixed at the earliest possible date on which up-to-date information as to the present cost of living and the effect of the Rent Restriction Act will be available, there does not appear to be any justification for the action which is now being taken in Manchester."

Dealing with the situation, Mr. C. W. Bowerman, M.P., president of the National Printing and Kindred Trades Association, and chairman of the Joint Industrial Council for the printing trades, is reported to have said that "if the men concerned take the course of action proposed, they will be entering upon it with their eyes open, and it will create a very serious position. The matter of the dispute has been constitutionally dealt with as between the respective societies and the men's own organisation, the Typographical Association. The result of the conference at the Stationers' Hall some few weeks ago, has been accepted by every society and every branch, with the exception of the Manchester and Liverpool branches of the Typographical Association. As I understand, these branches have practically defied their own executive, and taken their own course. When one remembers that there is a body in existence—the Joint Industrial Council—which has rendered good service to the trade, it makes it all the more regrettable that action of this kind should be taken."

A settlement has been arrived at in the dispute between the Association of Wireless Telegraphists and the Wireless Companies in regard to salaries and conditions of service.

The demand put forward on behalf of the men was for 177 per cent. increase over pre-war rates, and the result of the settlement is the granting of an average increase of 156 per cent. The question of examinations which the wireless companies desired to institute has been waived, the association contending that the three examinations required by the Government were sufficient to secure efficiency and covered the same ground as the wireless companies' proposed examinations. The war bonus has been merged into salary as from May 1 at the rate of 60*l.* per annum, and the increases in salary are retrospective to May 17. In future a risk allowance of 7½ per cent. on salary is to be paid during service on oil tankers. The provision whereby the short allowance of 3*s.* 6*d.* per day was not payable until the lapse of seven days after arrival in port has been waived, and this allowance will now be paid from the day after signing off articles until the day before re-engagement, and the in-charge allowance of 5*s.* per week payable during the first three years of service when men are in charge of a ship's station will be continued. The scale payments are the following: Grade I: 22*l.*, 24*l.* and 25*l.* per month; Grade II: 16*l.*, 18*l.* and 20*l.*; Grade III: 11*l.*, 12*l.* and 14*l.* The Marconi Company intend to institute a higher class, composed of sea-going operator inspectors on a scale of 26*l.*, 28*l.* and 30*l.* per month for service on the large liners. The baggage allowance of 7*s.* 6*d.* has been increased to 10*s.* A change has been made in the foreign service allowance whereby, instead of a fixed sum per week, the National Maritime Board regulations governing salaries plus a percentage for that service will be instituted in future. Annual leave of two weeks on salary without shore allowance will be given. Sick leave has been reduced from eight weeks in any consecutive twelve months on full pay to 14 days on half the actual salary, less the amount received from the National Health Society.

The agreement has been signed by the London and District Association of Engineering Employers, the Marconi Company, and the Association of Wireless Telegraphists as from August 26. The settlement has been accepted by the membership on the recommendation of the Executive Committee of the Association of Wireless Telegraphists.

According to *The Glasgow Herald*, the dispute between the platers and their helpers in Clyde shipyards has not yet been altogether settled, although the Industrial Court, in their recent award interpreting the advance granted some time ago, in so far as it applied to platers' helpers, decided that the advance to the helpers should be paid by the platers. In the great majority of the yards the platers are now paying the helpers the full 6*s.* per week advance on time rates awarded by the court, but in several yards on the upper reaches the helpers state that they are being paid only 3*s.* 9*d.* per week, and they are, in consequence, on strike. Only two yards were at first thus affected, but last week the helpers in a third yard stopped work for the same reason. In these circumstances it may be interesting to give in detail the earnings of the platers and the helpers in one of the yards in the area in which the helpers are still on strike. The following tables, which apply to one week before the Fair Holidays and three weeks since, show the average which the piece-work platers lifted per man per week:—

Week ending.	Per Hour. £ *s.* *d.*	Per Week. £ *s.* *d.*
Frame Squad.		
July 13 ...	0 6 11	16 5 1
August 3 ...	0 5 2½	12 4 9½
August 10 ...	0 4 11	11 11 1
August 17 ...	0 5 4½	12 12 7½
Beam Squad.		
July 13 ...	0 5 1	11 18 11
August 3 ...	0 5 4	12 10 8
August 10 ...	0 5 3½	12 8 8½
August 17 ...	0 5 2½	12 4 9½
Deck Squad.		
July 13 ...	0 5 1½	11 19 10½
August 3 ...	0 5 4	12 10 8
August 10 ...	0 3 10½	9 2 1½
August 17 ...	0 5 2	12 2 10
Shell Squad.		
July 13 ...	0 5 10½	13 15 1½
August 3 ...	0 5 9	13 10 3
August 10 ...	0 5 9½	13 12 2½
August 17 ...	0 5 11½	14 1 0½
Casing Squad.		
July 13 ...	0 4 1	9 11 11
August 3 ...	0 4 4½	10 5 7½
August 10 ...	0 3 7½	8 9 4½
August 17 ...	0 4 5	10 7 7
Jobbers (Average).		
	0 3 6	8 4 6

These sums include all bonuses and percentages, so that the figures represent the complete earnings of the men for the specified weeks. In contrast with this it may be explained that the time rate paid to helpers was 1*s.* 10½*d.* per hour, or a total of 4*l.* 9*s.* 7*d.* for the week of 47 hours. The difference between these rates of earnings makes all the more marked the objection of the platers to pay their helpers the additional 2*s.* 3*d.* per week required to carry out fully the award of the Industrial Court. It is also pointed out that the helpers, though ranking as unskilled men, do a large amount of the responsible work, and that their time rates in relation to the importance of their work are not so high as are the piece rates earned by the platers. The platers, it may be added—who in this particular matter act as "employers"—are members of the Boilermakers' Society, while the helpers are members of the National Amalgamated Union of Labour—a labourers' trade union—and the difficulty has arisen through the attitude of the highly-paid platers towards their time-working "employees."

TAR ACIDS IN DRAINAGE FROM TARRED ROADS.—From experiments by Mr. A. J. Mason-Jones, of the Joint Fisheries Committee, it is known that water contaminated by tar and containing 1 part of acid per 100,000 is fatal to fish life. Dr. J. J. Fox and Mr. A. J. H. Gauge, of the Government Laboratory, have worked out a method of determining very minute proportions of tar acids in water. The reagents required are colourless sulphanilic acid, sodium nitrite, sulphuric acid and caustic soda, and the experiments were made with cresol solution and other tarry products. On mixing the reagents an orange-coloured diazotised dye is formed in the presence of tar acids. The test should be made soon after collecting the sample, because the tar acids oxidise in the presence of certain bacteria. It is not said, unfortunately, in the paper by Fox and Gauge (Journal of the Society of Chemical Industry, August 16 last) that this oxidation is sufficiently rapid to protect the fish when rivers are polluted by road washings or by factory effluents.

STEAM ACTION IN SIMPLE NOZZLE FORMS.*

By Professor A. L. MELLANBY, D.Sc. and WM. KERR, A.R.T.C.

Introductory.—The problem of the expansion of a fluid through a nozzle is one of outstanding practical importance and of great theoretical interest. It has been the subject of various analytical efforts and of a multitude of experimental researches, and yet but little is really known as to how the internal action proceeds or the cost of its various processes. This is clearly shown by the purely presumptive forms of the law of expansion usually assumed as applicable in widely varying cases.

Consideration of the main difficulties in nozzle flow will readily derive their certain dependence on the internal actions in the jet itself, and, therefore, any degree of elucidation can only be achieved by a study—analytical or experimental—of the internal jet conditions which result from the varying boundary and fluid conditions imposed. Proving the establishment of the general facts of the flow by the ordinary, and well-used, experimental methods, it would seem that the call was upon analysis for the primary detail guidance. Unfortunately, the hydrodynamics of expanding compressible fluids presents extraordinary difficulties, even relatively to the not exactly simple problems of the flow of incompressible liquids. Consequently, the trend of advance is almost certainly a step by step delineation by experiment, no doubt assisted at times by odd flashes of mathematical insight.

In taking a general view of the extensive experimental work on this subject the observer is struck by the restriction of method in the more comprehensive researches, to one, or a combination of two, out of three main methods. These methods are:—Determination of flow, of reaction and of impact. In addition some experiments have been made by the "search tube" method, in which the pressure fall along the jet is observed. These are, however, of minor extent, and have only resulted in more or less confusing curves of pressure variation. The method cannot, indeed, so far claim to have added much to the useful or exact knowledge of the internal occurrences which it, presumably, is meant to portray.

Of flow measurements little more can be said than that they determine the flow in the individual cases examined. Deductions from such tests have been, in many cases, greatly upset by the anomaly of excessive discharge, now taken as well established, and by the accepted explanation thereof, based on the supposed super-saturated condition of the expanding steam. Coefficients of discharge may readily be obtained for different nozzle types in this way, but, unless the expansion is confined entirely to the superheat field, these are not valid for general application, since the supersaturated condition will undoubtedly disturb them by the indefiniteness of its occurrence and its likely variation in degree. Any examination of the expansion by the simple process of mass flow admittedly only considers the action to the throat, since that determines the quantity passed. Now the method actually throws but little light on the throat condition since, for all except perfect expansion, there are a number of throat conditions showing different efficiencies which give the same flow as based upon area. Since, therefore, the throat condition is not rigorously defined by the flow, the method is not serviceable for efficiency determinations, even for expansion between inlet and throat. Hence, if employed as a main method, flow determination has a very restricted use, and is only applicable with reasonably high superheats. It may be recalled that most of the classical experiments of this type commonly quoted do not fulfil this condition. The method is, of course, of definite value as a supplementary determination in aid of subsequent experimental analysis, as the mass flow is the one necessarily constant quantity in the equation of continuity.

Reaction determinations would seem to be of distinct value in arriving at total efficiencies of expansion. The method, however, provides "overall" information only, and fails entirely to give any indication of internal effects. It might be imagined that comprehensive research of this type could determine the influence of, say, entry curve on the expansion, by dealing with nozzles having this as a variable factor of form. But this is not so, since change of entry could, and may, alter the conditions of flow in the following parts, and the result, as obtained, would only show the balance of change. Again, the reaction effects are usually based on the expansion ratio of exhaust and supply pressures, but it is by no means certain that the range of the actual nozzle operations, on which the reaction depends, is in exact agreement therewith. It would seem necessary to accompany this determination with a measurement of the exact action range of the nozzle itself.

The measurement of impact effect is probably of use for direct application to turbine work, but as a method of pure research on nozzles it is hardly satisfactory. Like the reaction method it is of the "overall" type, but it has the additional demerit that it includes in its consideration any occurrence beyond the nozzle mouth, since the impact plate cannot be made coincident with the outlet.

Both reaction and impact processes are methods of search for the jet energy. They give entirely similar information, and should show essentially equal results. This equality is, however, not obtained. Morley† has demonstrated quite a considerable difference and, under his conditions, the impact exceeded the reaction. This difference has been ascribed to the establishment of a vortex coaxial with the jet, but on a general basis it is perhaps unnecessary to envisage this in order to imagine a probable discrepancy; a difference of the opposite nature hardly appears impossible. The actions in the free space beyond the nozzle are frequently peculiar; a rapid free expansion in a short length after efflux from the mouth is possible in certain cases, and there is always the probable occurrence of vibratory free flow with its inherent losses. All things considered the impact method seems less sound than the reaction as an examination of the expansion efficiency of the nozzle itself. Detailed observation of the action in the free space would be necessary to relate the two different results and since this may be affected by various accidental factors it is unlikely that the relationship would be finite and general.

From these considerations of the three leading methods of inquiry it will be seen that they are all of one class; each is a measure of some "overall" effect, and any combination of them serves only to amplify information of this nature giving, at the best, but a limited range of knowledge regarding the flow. In short, the variety is more apparent than real. No light whatever can be thrown on the interior happenings by such processes, and the distribution of the losses throughout the expansion remains mysterious.

On the other hand the "search tube" method is entirely one of internal examination, but it only serves to determine one of the factors involved, and is therefore, of itself, insufficient. But it would seem necessary to believe that some such process should be an essential part of a nozzle research scheme. This pressure measurement is the simplest of the "internal" methods. Temperature observations are troublesome to obtain, and are perhaps less valuable, while velocity or density determinations present many difficulties.

It has seemed desirable to discover how much information could be extracted from experiments combining the simplest of the "internal" methods with the simplest of the "overall" methods, *i.e.*, "pressure-flow" experiments. No doubt further combination with the reaction method would be still more valuable, but this would lead to complications rather undesirable at first, and, indeed, such developments could afford to await the demonstration of their necessity.

The experiments now under consideration were commenced some years ago, and some of the results were communicated by one of the authors during the discussion of a paper on "Steam Nozzles," by Professor J. Henderson.* In that communication the importance of experimental work with superheated steam was emphasised, and it was suggested that the solutions of several of the problems associated with the flow of steam might be found by research on these lines. The work was carried still further by the late Mr. F. J. Shepherd, B.Sc., who, among other experiments, obtained an interesting series of pressure curves by means of a "search-tube." These curves, when analysed, showed several important features but, unfortunately, the original data was not found amenable to full treatment, principally on account of the lack of flow measurements, and the unsuitability of the initial conditions. This led to a desire to repeat and extend the tests, with a view to submitting the new results to analysis, the aim being to study the internal nature and losses of the expansion in the simplest nozzle forms.

In the present paper it is only proposed to outline the method of analysis and to discuss general points arising therefrom. While actual experimental results are used in places it is in a qualitative sense only, the complete examination of the experimental data being deferred to a later section.

The Reheating Effect and the Jet Function.—The point universally recognised in nozzle action is the existence of a critical pressure, imposing a definite throat condition and minimum cross section for maximum flow. The ratio of this pressure to the pressure of supply is readily evolved from the equations of perfect expansion, being ·546 for superheated (or supersaturated) steam and, approximately, ·58 for wet steam. Of course, the actual expansion is imperfect, but this is not customarily supposed to affect the throat condition to any appreciable degree.

Now it has to be realised that the flow of a gas into and through a nozzle is liable to adventitious influences arising anywhere in the jet length. Thus, too fine an entry, too quick a curve, too large a throat, a wire edge, inconvenient path of approach, errors in the divergence and faults on the boundary surfaces would all have their due effects at the points where they occur; and these effects would have their influence on the actual flow, on the jet form and on the expansion law.

In nozzle work the examination of the simultaneous pressure and volume conditions is frequently effected by assuming that the expansion of the gas can be closely approximated by the $P V^n$ law, the index value being adjusted to suit initial and final conditions. Other assumptions, such as a uniform efficiency of expansion or a percentage loss proportional to the available energy, are also common. But consideration of the above points should help to a realisation of the fact that these approximations, though simple, are not necessarily sound. Expansion of any type whatever must be considered as resulting from the accidental hindrances imposed either by design or construction. Thus in Fig. 1 the $P V^n$ curve, suiting the initial and final conditions, is by no means an approximation to the arbitrary real expansion curves (A, B and C) indicated, and these latter cannot be ridiculed until it is known that they are impossible. In reality the smoothed curve is coincident with the actual at only two or three points throughout the whole range and, therefore, the fluid conditions are, in general, not similarly defined for the same position on the jet. Hence it follows that the jet conditions and flow are functions of the actual expansion path, and are not even approximated, with any serviceable degree of closeness, by smoothing out that path. The assumption of $P V^n$ = a constant is only allowable when the curve is nearly straight, as when the expansion takes place at constant efficiency. Now a constant efficiency is an unlikely condition in nozzle expansion, since the potential value of a fault in nozzle form, area or finish, is manifestly dependent on its position. The conclusion is therefore reached that in order to study possible variations in the internal conditions of a jet, any kind of expansion must be envisaged, and a special form, such as given by the $P V^n$ law, relegated to its proper place as merely one type, and not as a permissible approximation to all types. Consequently it is desirable to develop a simple method capable of embracing widely different expansion types.

Imagine a nozzle expanding fluid to such a degree that, at all times throughout the expansion, the fluid condition is restricted to one field, for which the index n for the reversible adiabatic is fixed and definite. Beyond what is contained in this postulate no limit is stated for initial conditions of supply. If the expansion is perfect then the usual theory, employing the adiabatic relation, gives for the flow per second per unit of area:—

$$\frac{G}{A} = \frac{1}{144}\sqrt{\frac{288\,g\,n}{n-1}\,\frac{P_1}{V_1}\,\frac{1-r^{\frac{n-1}{n}}}{r^{\frac{2}{n}}}}$$

Wherein G = mass flow, pound per second.
A = area, square inches.
P_1 V_1 = initial conditions; pressure lb. per square inch, volume cubic foot per pound.
r = pressure ratio = P/P_1.

If n is taken at 1·3 (as suitable for superheated steam) this may be expressed:—

$$\cdot 718\left(\frac{V_1}{P_1}\right)^{\frac{1}{2}}\frac{G}{A} = \frac{r\left(1-r^{\frac{n-1}{n}}\right)^{\frac{1}{2}}}{r^{\frac{n-1}{n}}} \quad . \quad . \quad (1)$$

Now this means that this nozzle, operating with any initial conditions, but always in same field with same pressure ratio, passes a quantity such that:—

$$\cdot 718\left(\frac{V_1}{P_1}\right)^{\frac{1}{2}}\frac{G}{A} = \text{a constant.}$$

Suppose, however, that the expansion is imperfect. Then G/A will be less for any—the same—initial conditions. Hence also the right hand side of (1) will be reduced. If, again, experiment should demonstrate that, even for imperfect expansion, such as must exist in experiment, the quantity given by the left hand side of (1) is reasonably constant for this particular nozzle, then it follows that this value has been reduced by some definite amount due to the losses incident on such an expansion ratio, and the right hand side could be expressed in any manner suitable to a reduced value, *e.g.*:—

$$\frac{r\left(1-r^{\frac{n-1}{n}}\right)^{\frac{1}{2}}-a}{r^{\frac{n-1}{n}}+b}$$

But an equivalent correction could be introduced thus:—

$$\frac{r\left(1-k-r^{\frac{n-1}{n}}\right)^{\frac{1}{2}}}{k+r^{\frac{n-1}{n}}}$$

k being always positive.

It must be understood that r is the ratio of operation of the nozzle only, and not the ratio of exhaust and supply pressures, since a nozzle may easily be of such a form as will cause an excess or effect only a partial expansion.

Since k is a quantity reducing the value of the ideal expression it must be a loss factor of some type, indicating how the action for the stated ratio falls short of the ideal, and it must be a constant for this ratio if:—

$$\left(\frac{V_1}{P_1}\right)^{\frac{1}{2}}\cdot\frac{G}{A}$$

is demonstrably constant. It may be readily shown that the introduction of this single symbol adequately expresses the reheating effect due to the losses. Obviously, for the actual occurrence:—

$$\frac{G}{A} = \frac{1}{144}\sqrt{\frac{288\,g\,n}{n-1}\,\frac{P_1}{V_1}\,\frac{r^2\left(1-k-r^{\frac{n-1}{n}}\right)}{\left(k+r^{\frac{n-1}{n}}\right)^2}}$$

$$\text{or}\quad \frac{G}{A} \propto \frac{\sqrt{P_1 V_1\left(1-k-r^{\frac{n-1}{n}}\right)}}{\frac{V_1}{r}\left(k+r^{\frac{n-1}{n}}\right)}$$

But by the equation of continuity:—

$$\frac{G}{A} \propto \frac{u}{V} \propto \frac{\sqrt{E}}{V}$$

where u = velocity
and E = energy drop.

Now, since $P_1 V_1\left(1-r^{\frac{n-1}{n}}\right)$ is proportional to the adiabatic drop it is readily seen that $P_1 V_1 k$ represents the loss of energy in the expansion, provided that $\frac{V_1}{r}k$ is the increase of volume arising from the reheating due to that loss. The value $\frac{V_1}{r}r^{\frac{n-1}{n}}$ is, of course, the volume on the adiabatic.

That this increase of volume agrees with the reheating effect may readily be seen from the P V diagram in Fig. 2. In this the area a, b, c represents $P_1 V_1 k$, and $\overline{V_2 V_2'}$ the increase of volume. Hence:—

* Paper read before Section G of the British Association at Cardiff, August 26, 1920.
† Proc. I.M.E., January 21, 1916.
* Proc. I.M.E., February, 1913.

$$\text{Area } \overline{V_2{}^1\ b\ c\ V_2} = \text{Area } \overline{a\ b\ c}$$

$$\therefore P_2(V_2 - V_2{}^1) = P_1 V_1 k$$

$$\therefore V_2 - V_2{}^1 = \frac{V_1}{r} k$$

$$\therefore V_2 = V_2{}^1 + \frac{V_1}{r} k = \frac{V_1}{r}\left(k + r^{\frac{n-1}{n}}\right)$$

Consequently the relation corresponding to (1), but applicable to the actual expansion is :—

$$\cdot 718 \left(\frac{V_1}{P_1}\right)^{\frac{1}{2}} \frac{G}{A} = \frac{r\left(1 - k - r^{\frac{n-1}{n}}\right)^{\frac{1}{2}}}{k + r^{\frac{n-1}{n}}} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The result so obtained by argument can be simply and directly derived by the use of Callendar's equations for steam, if the small terms appearing therein are neglected.

The equation for specific volume is :—

$$V = \frac{a}{P}(H - 835) + c$$

where $a = 1 \cdot 2464$, c = small term.

Neglecting small term and writing :—

$$I = H - 835$$

the simple relations are obtained :—

$$V = \frac{a\,I}{P}, \quad I = \frac{P\,V}{a}.$$

If the expansion is adiabatic, $P(V - b)^{1 \cdot 3} = a$ constant, where b is a small term, and the end condition on the adiabatic is :—

$$I_2{}^1 = \frac{P_2\,V_2{}^1}{a} = \frac{P_1\,V_1}{a} r^{\frac{n-1}{n}}.$$

Now, allow that losses have been taking place such that at P_2 there has been a reheat of the steam represented by i units, then the actual conditions at P_2 are :—

$$P_2,\ V_2,\ (I_2{}^1 + i)$$

Hence :— heat drop $= h_2 = I_1 - (I_2{}^1 + i)$

specific vol : $= V_2 = \frac{a}{P_2}(I_2{}^1 + i)$.

If i is defined thus :—

$$i = \frac{P_1\,V_1}{a} k$$

then :—

$$\text{velocity} = u_2 = d\left(\frac{P_1\,V_1}{a}\right)^{\frac{1}{2}}\left(1 - k - r^{\frac{n-1}{n}}\right)^{\frac{1}{2}}$$

where d = constant

$$\text{volume} = V_2 = \frac{V_1}{r}\left(k + r^{\frac{n-1}{n}}\right)$$

and if these are substituted in the equation of continuity :—

$$\frac{G}{A} = \frac{u}{144\,V}$$

there is at once obtained :—

$$\cdot 718 \left(\frac{V_1}{P_1}\right)^{\frac{1}{2}} \frac{G}{A} = \frac{r\left(1 - k - r^{\frac{n-1}{n}}\right)^{\frac{1}{2}}}{k + r^{\frac{n-1}{n}}} \quad . \quad . \quad . \quad . \quad (2)$$

The first process of derivation is perhaps the more general, since no particular fluid is necessarily specified. The second demonstrates that the margin of error in the application to steam is that involved in discarding the small terms in Callendar's equations, an error well within the range of that due to experiment. The result, with the necessary change in the constant, is applicable to the flow of any gas, provided always that the assumptions made are allowed. As these are important, they may be again clearly stated.

(i) That reversible adiabatic expansion can be represented by the law $P V^n = a$ constant throughout the whole field within which the nozzle operates, without change of n.

(ii) That, for any given nozzle with a given pressure ratio restricted to the nozzle itself, the quantity :—

$$\left(\frac{V_1}{P_1}\right)^{\frac{1}{2}} \frac{G}{A}$$

is a constant.

The first is readily admissible, although if steam is employed it defines a lower limit of superheat in the supply conditions. The second is rather different and involves an appeal to experiment for substantiation, although those familiar with practical turbine and nozzle work will probably recognise it as a well-known and handy relation regarding the flow through fixed areas.

The readiest evidence comes from the widely used rule that, for a turbine with unalterable areas working under various receiver conditions the flow is given by* :—

$$G \propto \sqrt{\frac{P_1}{V_1}}$$

which directly satisfies the requirement.

Morley's † experiments on the flow of air through nozzles have shown that the mass flow per second, through a given nozzle, is proportional to the pressure, the temperature being practically constant. Hence since $G \propto P$ and $P\,V$ is constant, it follows that :—

$$\left(\frac{V_1}{P_1}\right)^{\frac{1}{2}} \frac{G}{A} = \text{a constant}$$

This result is, of course, not quite general as determined by these experiments, since the temperature was not varied.

Again, Table I shows a few values as determined for a convergent-parallel nozzle supplied with superheated steam at different conditions, from which it will be seen that the constancy of this quantity is fairly definite :—

TABLE I.—*Values of* $\left(\frac{V_1}{P_1}\right)^{\frac{1}{2}} G$ *for a Convergent-Parallel Nozzle, with Varying Supply Conditions and Expansion in Superheat Field.*

Pressure of Supply P_1 (abs.)	Exhaust Chamber Pressure P_2 (abs.)	Ratio P_2/P_1.	Initial Temperatures. Deg. F.	Specific Volume. V_1.	Action Ratio of Nozzle. r.	Weight Flow. Lb.	Duration of Test. Sec.	$\left(\frac{V_1}{P_1}\right)^{\frac{1}{2}} G$
106·4	50.2	.472	431	4.830	.505	60	1107	.01155
74.9	34.1	.456	525	7.686	.505	58	1606	.01154
44.8	20.2	.451	578	13.525	.505	39	1875	.01143

Another point of view may be adopted in this matter. Since no restriction has been specified as to where the area A is taken, the constancy of the quantity in question must involve a constant value for any position chosen on the jet. But r will also vary with position, hence k must be a function of r and will vary along the jet in some fashion as r alters. This simply means that the curve showing fall of pressure ratio will remain the same, despite changes in the conditions of supply. Again, verification may be sought in experimental results.

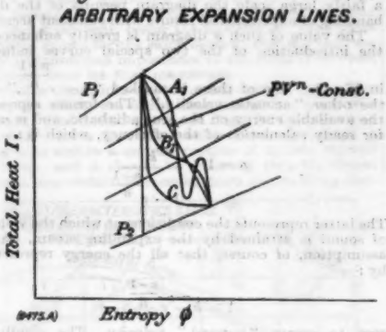
A series of curves of the actual fall of pressure along an air jet, expanding in a convergent-parallel nozzle, is shown in Fig. 3. The values for the plotting of these were determined by use of a search-tube, readings being taken every 1/32 in. of length. In order to achieve the same pressure ratio for the nozzle in each case, it is only necessary to keep the exhaust chamber pressure below the expanding power of the nozzle. As, under the circumstances of these experiments, the lowest back pressure was atmospheric, the desire to obtain a fairly wide range of initial pressure forbade the use of a divergent nozzle; hence the restriction to the parallel type that is probably noticeable in these corroboratory experiments. When the results shown by Fig. 3 are plotted as pressure ratio ordinates the points fall very closely on the single curve shown in Fig. 4. Again, the qualification is to be noted that the variation in supply conditions did not include temperature changes.

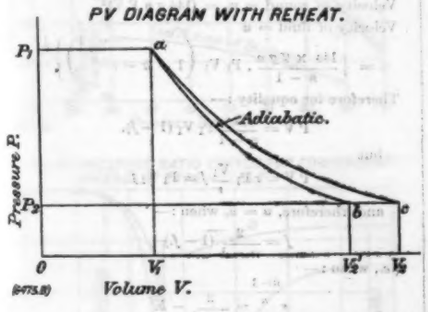
In Fig. 5 the pressure ratio curve for the nozzle results stated in Table I is shown. The supply conditions involve changes of pressure and temperature, and it will be seen that the points for the different conditions lie very fairly on the one curve.

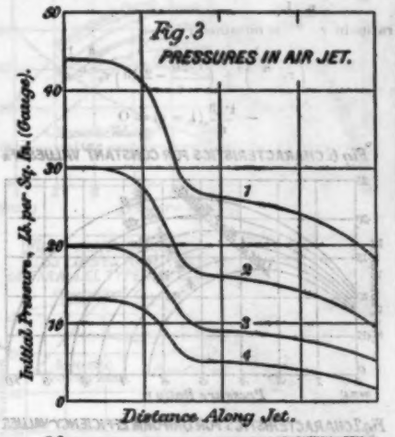
On consideration of the evidence submitted it will probably be allowed that there is practical agreement with the specified relation. At the same time, it is desirable to remark that no claim can be made as to the perfect accuracy of this matter. The small terms in Callendar's equations militate against this, even if nothing else does: but its close agreement with actual observation, apparently within the limits of error inherent in absolute flow measurement, would seem to render it a suitable assumption in all cases involving such measurements.

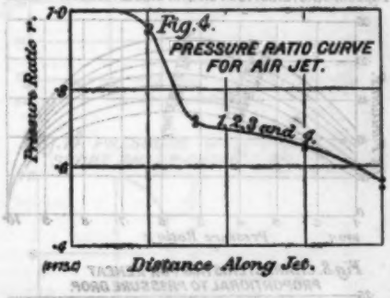
Since the conditions under which equation (2) was established are now clearly verified, it may be taken that that equation is directly applicable to the actual expansion by a nozzle provided these conditions are not transgressed.

The equation, therefore, defines the flow and the loss for given initial conditions; or, for a given nozzle operating under stated conditions, and carrying a definite quantity per second, it defines the pressure for any given flow area. The right-hand side of (2) determines the reheating effect k, corresponding to the pressure shown by r and the flow area represented by A. Consequently,









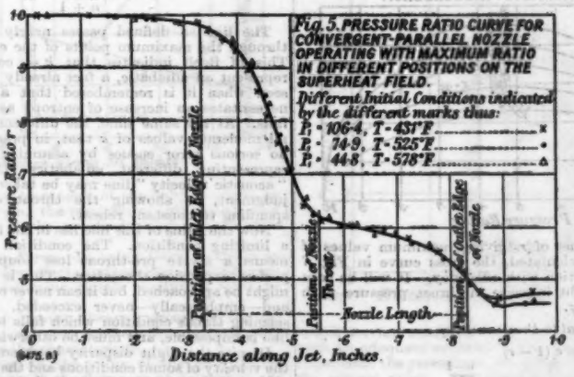


Fig. 5. PRESSURE RATIO CURVE FOR CONVERGENT-PARALLEL NOZZLE OPERATING WITH MAXIMUM RATIO IN DIFFERENT POSITIONS ON THE SUPERHEAT FIELD.
Different Initial Conditions indicated by the different marks thus:
P_1 = 106·4, T = 431°F. ×
P_1 = 74·9, T = 525°F. •
P_1 = 44·8, T = 578°F. △
Pressure Ratio r
Position of Inlet Edge of Nozzle
Position of Nozzle Throat
Position of Outlet Edge of Nozzle
Nozzle Length
(9475.B)
Distance along Jet, Inches.

* See also "The Flow of Steam into a Compound Steam Turbine," ENGINEERING, July 7, 1916.

† Proc. I.M.E., January, 1916.

it has rather important applications in the study of the internal jet conditions, and may be termed the "jet function," and written :—

$$F = \frac{r\left(1-k-r^{\frac{n-1}{n}}\right)^{\frac{1}{n}}}{k+r^{\frac{n-1}{n}}} \quad . \quad . \quad . \quad (3)$$

The simplicity of the process is rather noticeable, but the subject does not seem to have been dealt with in this way before, and the authors, while apologising for treating such a simple matter at such length, have deemed it an essential duty to deal rather fully with the points and the limits involved in this basis of examination.

The Characteristic Curve.—It has been shown that k is a function of r, and that the curve of pressure ratio is constant for a particular nozzle operating under a given ratio of action. It therefore follows that the graph of the jet function for this ratio will be peculiar to the nozzle, and may be referred to as its "characteristic curve." The form of this curve will simply depend on the nature of the loss, and it is instructive to study it for some arbitrary k values to establish the effects of certain occurrences on form.

The jet function is :—

$$F = \frac{r\left(1-k-r^{\frac{n-1}{n}}\right)^{\frac{1}{n}}}{k+r^{\frac{n-1}{n}}},$$

writing :—

$$k + r^{\frac{n-1}{n}} = f$$

then :—

$$F = r f^{-1}(1-f)^{\frac{1}{n}}$$

and differentiating :—

$$\frac{dF}{dr} = \frac{f(1-f) - r\frac{df}{dr}\left(1-\frac{f}{2}\right)}{f^2(1-f)^{\frac{1}{n}}}$$

and F will be a maximum when $\frac{dF}{dr} = 0$, *i.e.*, when :—

$$\frac{r}{2f}\cdot\frac{df}{dr} = \frac{1-f}{2-f} \quad . \quad . \quad . \quad (4)$$

This equation gives the condition of minimum flow area, and therefore defines the pressure ratio r_c at the throat for the law of k assumed. It can only be obtained directly for simple cases, but for more complex cases the graphical method is not only necessary but desirable.

All the points to be dealt with throughout this work refer to the flow of superheated steam, and hence throughout the calculations the index n is taken as 1·3.

Reversible Adiabatic Expansion :—

$$k = 0,\ f = r^{\frac{n-1}{n}}$$

$$F = \frac{r\left(1-r^{\frac{n-1}{n}}\right)^{\frac{1}{n}}}{r^{\frac{n-1}{n}}}$$

This curve is shown, marked $k = 0$ in Fig. 6. For the throat ratio, r_c, equation (4) gives :—

$$\frac{n-1}{n} = \frac{1-r_c^{\frac{n-1}{n}}}{2-r_c^{\frac{n-1}{n}}}$$

$$\therefore \quad r_c = \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}} = 0.5457.$$

Heavy Loss at Commencement of Expansion :—

$$k = 1 - r^{\frac{n-1}{n}} \quad \text{for } r = 1 \text{ to } r = r_a$$

and

$$k = 1 - r_a^{\frac{n-1}{n}} = \text{constant thereafter}$$

In this case the k value assumes that all the heat available between $r = 1$ and $r = r_a$ is reheating the steam, due to some severe losses at commencement; consequently, it is just as if the expansion were beginning at a lower initial pressure and, hence, the throat ratio will be, approximately, given by :—

$$r_c = 0{\cdot}5457\, r_a,$$

since the expansion is nearly perfect from the lower pressure. Thus if $r_a = 0{\cdot}85$, $r_c = 0{\cdot}5457 \times 0{\cdot}85 = 0{\cdot}465$.

This is, however, not rigorously exact, since k is a reheating value and, therefore, if constant, entails a slight growth of entropy after the period of loss assumed. It will be seen on examination of the curves for the various k values shown in Fig. 6 that this treatment does give a very close approximation to the maximum values; the cross curve showing these positions determined as above. It is clear that growth of k on this basis means definite reduction of throat pressure.

Expansion with Uniform Efficiency η :—

$$k = (1-\eta)\left(1-r^{\frac{n-1}{n}}\right)$$

$$f = 1 - \eta\left(1-r^{\frac{n-1}{n}}\right)$$

$$F = \frac{r\,\eta^{\frac{1}{n}}\left(1-r^{\frac{n-1}{n}}\right)^{\frac{1}{n}}}{1-\eta\left(1-r^{\frac{n-1}{n}}\right)}$$

A series of curves for different efficiency values is given in Fig. 7.

For the throat ratio r_c equation (4) gives :—

$$\frac{\frac{n-1}{n}\eta r_c^{\frac{n-1}{n}}}{2-2\eta\left(1-r_c^{\frac{n-1}{n}}\right)} = \frac{\eta\left(1-r_c^{\frac{n-1}{n}}\right)}{1+\eta\left(1-r_c^{\frac{n-1}{n}}\right)}$$

On reducing and substituting for n the following quadratic in $r_c^{\frac{n-1}{n}}$ is obtained :

$$\left(r_c^{\frac{n-1}{n}}\right)^2 + \left(\frac{1{\cdot}26}{\eta} - 2{\cdot}13\right) r_c^{\frac{n-1}{n}} - \frac{1{\cdot}13}{\eta}(1-\eta) = 0$$

Fig. 6. CHARACTERISTICS FOR CONSTANT VALUES OF k.

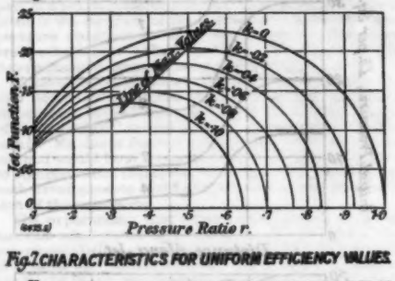


Fig. 7. CHARACTERISTICS FOR UNIFORM EFFICIENCY VALUES.

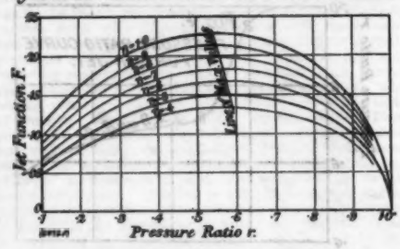
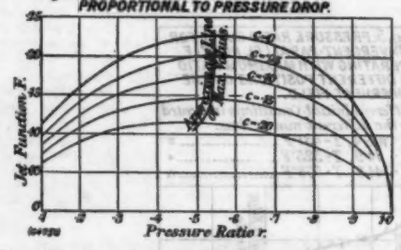


Fig. 8. CHARACTERISTICS FOR REHEAT PROPORTIONAL TO PRESSURE DROP.



From this, the values of r_c giving maximum values of F can be readily calculated, the cross curve in Fig. 7 indicating the variation with efficiency. It will be seen that there is a slight increase in throat pressure with decrease of efficiency.

Reheat Proportional to Pressure Drop :—

$$k_1 = c(1-r)$$

$$f = c(1-r) + r^{\frac{n-1}{n}}$$

$$F = \frac{r\left(1-c+cn-r^{\frac{n-1}{n}}\right)^{\frac{1}{n}}}{c(1-r)+r^{\frac{n-1}{n}}}$$

A few cases for different values of c are shown in Fig. 8. The analytical condition for r_c has now become rather unmanageable, viz. :—

$$\frac{\frac{n-1}{n}r^{\frac{n-1}{n}} - cr}{2c(1-r)+2r^{\frac{n-1}{n}}} = \frac{1-c(1-r)-r^{\frac{n-1}{n}}}{2-c(1-r)-r^{\frac{n-1}{n}}}$$

and the maximum positions are most readily, and with sufficient accuracy, determined directly from the curves. The rapid breakaway of the line of maximum values, shown at the higher measures of c, is due to the fact that the line of reheating effect given by :—

$$k = c(1-r)$$

actually lies above the available energy curve represented by the equivalent :—

$$1 - r^{\frac{n-1}{n}}$$

for a range of values of r which grows very rapidly as c increases. Thus up to $c = 0{\cdot}15$, k exceeds $1 - r^{\frac{n-1}{n}}$ only for a negligible period; at $c = 0{\cdot}20$, k recrosses the "drop" curve at about 0·975; while for $c = 0{\cdot}30$, k is an impossible value until r reaches 0·50. It is to be noticed, however, that within the practicable range of c the throat ratio is almost exactly in line with the theoretical 0·546.

It is quite an interesting exercise to study the forms of the characteristics resulting from arbitrary k curves of any type, and to consider the question of their applicability to special nozzle forms. This is most readily done by using a standard diagram of the kind shown in Fig. 6, containing curves of constant k. With a fairly large scale the diagram permits of the direct handling of experimental results with sufficient accuracy.

The value of such a diagram is greatly enhanced by the introduction of the two special curves indicated $1 - r^{\frac{n-1}{n}}$, in Fig. 9. One of these is marked "$1 - r^{\frac{n-1}{n}}$," and the other "acoustic velocity." The former represents the available energy on the true adiabatic, and is useful for ready calculation of the efficiency, which is :—

$$\eta = 1 - \frac{k}{1-r^{\frac{n-1}{n}}}$$

The latter represents the conditions at which the velocity of sound is attained by the expanding steam, on the assumption, of course, that all the energy represented by :—

$$1 - k - r^{\frac{n-1}{n}}$$

goes to create "onward" velocity. The conditions for this curve are easily established as follows :—

Velocity of sound $= u_s = (144\, g\, n\, P\, V)^{\frac{1}{2}}$

Velocity of fluid $= u$

$$= \left\{\frac{144 \times 2gn}{n-1} \cdot P_1 V_1 \left(1-k-r^{\frac{n-1}{n}}\right)\right\}^{\frac{1}{2}}.$$

Therefore for equality :—

$$PV = \frac{12}{n-1} P_1 V_1 (1-f).$$

but

$$PV = r P_1 \frac{V_1}{r} f = P_1 V_1 f$$

and, therefore, $u = u_s$ when :—

$$f = \frac{2}{n-1}(1-f.)$$

i.e., when :—

$$r^{\frac{n-1}{n}} = \frac{2}{n+1} - k.$$

The line so defined passes nearly but not exactly through the maximum points of the constant k curves. This of itself indicates that k = constant does not represent an adiabatic, a fact already noted, and easily seen when it is remembered that a constant reheat necessitates an increase of entropy as the temperature falls. At the same time, the difference is so slight for all moderate values of k that, in practical calculation, no serious error ensues by assuming these curves as representing different adiabatics. Consequently the "acoustic velocity" line may be taken, for purposes of judgment, as showing the throat conditions corresponding to constant reheat.

Now the value of this line lies in the fact that it marks a limiting condition. The condition of k = constant means a severe pre-throat loss coupled with almost perfect expansion thereafter. This is an action which might be approached, but it can never really be attained, and—emphatically—never exceeded. Consequently, a seeming throat condition which falls to the left of this line is impossible, and must be otherwise explained.

Despite the slight disparity between the line showing the velocity of sound conditions and the line of maximum values of the constant k curves, it has been considered desirable to deal with the former in preference. The physical significance of the acoustic velocity, and its application by Osborne Reynolds to the explanation of the critical pressure for perfect expansion, renders it always a valuable conception; and this extension to cases of imperfect flow increases its usefulness. The difference between the two lines referred to may appear slightly confusing, but it is due to the use being made of a reheating effect rather than an energy loss. In practical considerations the two lines may be looked upon as coincident.

It is probably advisable here to point out that the maximum line in Fig. 7 does not express any similar limit in the other direction, since there is certainly no reason for supposing that a uniform efficiency is a limiting condition of flow. It is quite easy to conceive almost perfect expansion at entry followed by heavy losses and, with a nozzle type of limited expansion range, this could easily result in apparently high throat pressures. This may already have been noticed in Fig. 4 with the air jet curve there shown to illustrate a different fact. The high pressure at the throat is a feature of expansion in convergent-parallel nozzles. The application, however,

of the term "throat" to the position at the end of the entry curve in this nozzle type is really faulty, although it has arisen very naturally.

The results already dealt with in a general way may be more concisely and clearly shown by specific examples. Assuming, for instance, an overall pressure ratio of 0·2, and a total reheat of 0·04 (corresponding to an overall efficiency of fully 87 per cent.) consider the three following cases :—

(1) Loss entirely before the throat.
(2) Loss proportional to pressure drop.
(3) Loss almost all beyond the throat.

These cases are shown in Fig. 9 by full lines, and it is seen therefrom that the throat ratios are :—

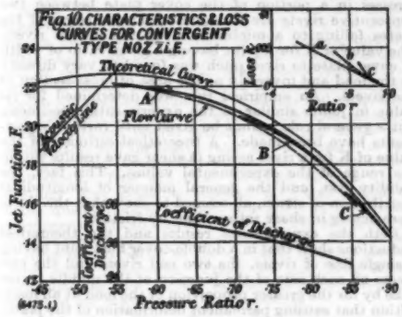
(1) $r_c = 0·46$ being 16 per cent. below the theoretical 0·546.

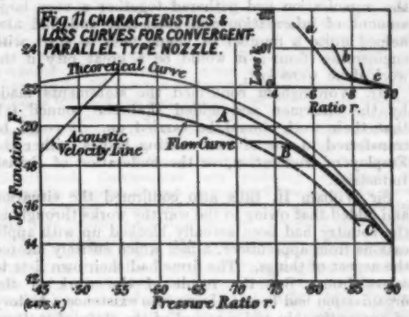
(2) $r_c = 0·55$ being practically equal to the theoretical.

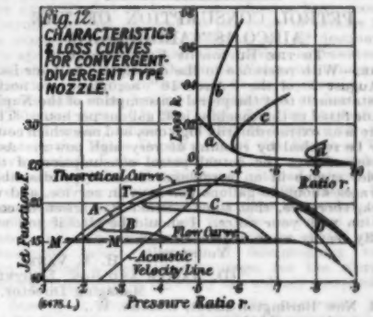
(3) $r_c = 0·57$ being 4 per cent. above the theoretical.

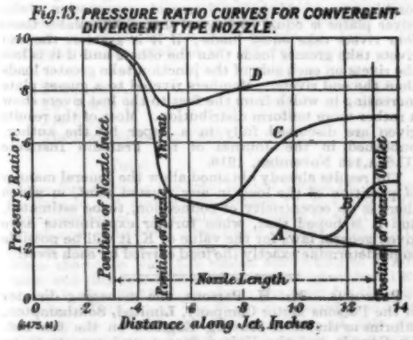
Again the flow quantities per square inch of actual throat section are, respectively, 18 per cent., 10½ per cent., and 2 per cent. below the theoretical. The great differences shown for the same overall efficiency indicate clearly the profound importance of the order of the loss as distinct from its final magnitude.

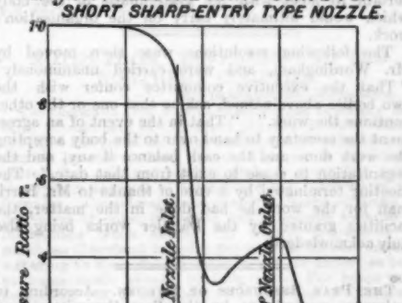
If similar conditions are assumed, but for larger loss values, the effects are of the same order, but more pronounced. The dotted curves in Fig. 10, for example, give results for a k of total value 0·08. Condition 1 in this case suffers a certain portion of its loss beyond the throat, and it should be observed that the throat condition has definitely receded from the limiting line.

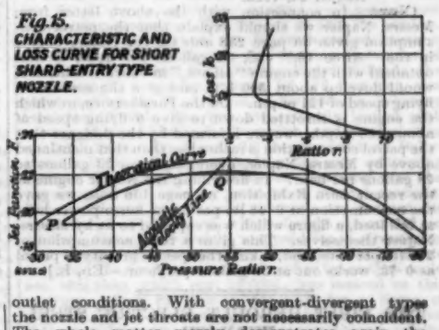












This introductory treatment of the subject might be concluded by applying the methods of this section to a brief examination of the peculiarities of a few nozzle types.

Effects of Nozzle Form.—In using these methods to examine the expansion effects and loss curves for different nozzle types the following simple conditions must be observed :—

(1) The value of k must always increase as the expansion proceeds ; any one constant k curve can only be crossed once by the characteristic.

(2) The variations in the value of the jet function must suit the changes in the flow area as defined by the nozzle form.

(3) The terminal points of a series of characteristics, representing different pressure ratios of operation, must be in consonance with the actual facts regarding variation of mass flow with change of outlet pressure.

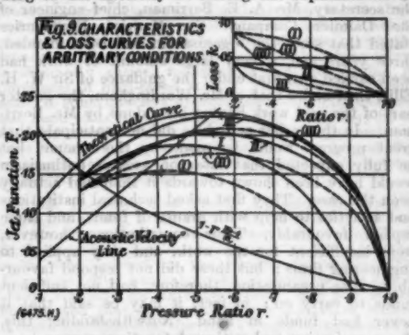
The first two conditions are more or less axiomatic, although the second fails in those special cases where the nozzle form is unable to compel the jet to conform with its outline throughout, *e.g.*, with a sharp entry or an excessive divergence. The last condition merely claims the use of facts well established by experiment.

Convergent Type.—Consider the assumed loss curve "*a*" in Fig. 10. When the corresponding values of F are plotted the characteristic "A" is obtained. Clearly, this case is applicable to the action in a simple convergent form, since the expansion is smooth and regular in a decreasing section, and maintained to a point near the critical value.

Now with such a nozzle it is well known that the coefficient of discharge falls steadily as the back pressure is increased. The highest point on this characteristic "A" represents the maximum flow, the coefficient of discharge being given by the ratio of F at this point to the value on the theoretical curve at the same pressure ratio. Using this as a starting point a probable curve of discharge coefficients may be sketched in as indicated, wherefrom the flow curve shown dotted may be obtained.

This curve is the locus of the terminal points of the characteristics for varying back pressure. Two of these are shown at "B" and "C," while the loss curves resulting from these are given by "*b*" and "*c*."

Convergent Parallel Type.—The procedure in this case is similar, resulting in the curves of Fig. 11. The form of the characteristic differs from the last case, owing to the necessity of suiting the expansion to a length having constant area. It is at once seen that, with an adequate entrance curve compelling continuous expansion, the pressure at the throat must be well above the critical value. The parallel length is being swept by relatively high speed fluid, and a very definite loss is thereby incurred. This loss will depend on the actual length of the tail piece ; and it would be expected that the flat part of the characteristic would be reduced in extent, the flow increased, the throat pressure diminished, and the outlet pressure practically unaltered by shortening the tail length. Experiment shows that all these results ensue.



Convergent-Divergent Type.—This type shows certain peculiarities and necessitates some argument, which it is hoped may not prove too elusive.

Assuming a loss curve of something the same type as for the convergent-parallel case, but covering the necessary wider range, the smooth characteristic, "A" Fig. 12, may be derived.

Now, suppose this curve is correct and represents exactly the real action in the nozzle. Then, on the ordinary ideas as to how this expansion takes place, the F values at the crown and terminal points of this characteristic should be in the inverse ratio of the nozzle mouth and throat areas. But these areas would be fitted on quite arbitrary assumptions as to losses, which, of course, may be nearly correct, but only by a coincidence could be exactly so. Assuming, for illustration, that the areas were arranged on a somewhat incorrect basis then, with the actual outlet condition coincident with the terminal point of the characteristic, the point representing the state at the nozzle throat must be below the turning value. It should not be above as that would denote an area *smaller* than is envisaged by the supposedly true characteristic.

Owing to the flatness of the curve near the crown, any point slightly below it on the left indicates a pressure considerably under the critical value. Thus, if the lines M M and T T are in relative agreement with the nozzle mouth and throat areas, the pressure at the nozzle throat is seen to be about 0·4. The tendency will, therefore, always be for the nozzle throat pressure to be low in this type, unless the areas are fixed for the loss that will actually occur—a matter requiring some profound knowledge. This effect is well shown by search-tube experiments, the nozzle throat pressure being invariably low.

The term nozzle throat is used advisedly, as it is essential in this particular case, to distinguish between that position and the actual throat of the jet. The jet throat pressure is, of course, at the rational value represented by the crown point of the curve, and the fact that it lies above the nozzle throat condition indicates a small contraction of the jet to suit the actual conditions of the expansion.

The consideration of the convergent-parallel nozzle showed that the losses affected the pressure at the throat. Here, again, we have a similar occurrence ; and in both cases it would seem that changes influencing the losses will react more seriously on the nozzle throat than on the outlet conditions. With convergent-divergent types the nozzle and jet throats are not necessarily coincident. The whole matter merely demonstrates again the importance of the order of the expansion losses.

The mass flow for a convergent-divergent nozzle remains constant to a high value of the pressure ratio, usually between 0·7 and 0·8. Thus a flow curve as shown in Fig. 12 would be applicable. For any terminal point taken on the flat top of this curve the characteristic connecting thereto must include the throat condition as established by the main characteristic, since the flow is unaltered. Thus curve forms given by "B" and "C" are of the type suitable to these conditions, and show clearly the large re-compression ranges possible in a divergent tail piece. The high speed of the fluid, which is distinctly above the velocity of sound, confines the re-compression to as short a length as possible, and a steep pressure gradient, which has its counterpart in the flat portion of the branch curve, is established in the tail piece.

With a terminal condition above about $r = 0·75$ new throat conditions are established, and a smaller flow results ; a curve for such a case being shown by "D."

To enable the different effects in this case to be followed as easily as possible, Fig. 13 is added to show approximately, the pressure changes inside the nozzle corresponding to the curve given.

Sharp Entry Types.—Frequently elementary nozzles are graded so that the short, parallel, sharp-entry type comes first. This form is, however, brought in last in this discussion, as consideration of its action quite naturally follows that of the convergent-divergent type.

With a sharp entry the expanding fluid is unable to conform to the nozzle outline at entrance, and the jet is clear of the wall of the nozzle. The expansion proceeds free of restraint, and with decrease of jet section, until the real throat condition is reached ; but, being then definitely clear of the boundary, it continues to expand until its now diverging profile again comes in contact with the wall. The jet then finds, as it were, that

it has expanded too far to suit the passage it still has to make, and immediately re-compresses.

This simple explanation would seem to cover the action at the entrance of any sharp-entry type. The search-tube invariably discloses what appear to be very low throat pressures with recompressions thereafter; but the low value is really an over expansion, and does not mark a throat condition. The nozzle actually behaves as if there were an imaginary, but effective, short convergent-divergent fitting at the inlet, compelling exceptionally rapid expansion, the subsequent recompression being created by passage through the real form.

One pressure ratio curve for a short, sharp-entry nozzle is shown in Fig. 14. Although the true throat condition is unknown, a characteristic may be constructed which is probable to a sufficient degree, such, for instance, as that shown in Fig. 15. An estimate of the contraction of area of the jet could be obtained by comparison of the F values at the points P and Q marked on the characteristic.

Although the nature of this effect at a sharp entry is not influenced by the length or divergence of the nozzle these factors reflect on the actual extent of the occurrence; and with a long parallel outlet it would seem necessary to believe that the recompression may commence before the jet really reaches the boundary wall.

Throughout this section the graphs are given merely in illustration of the different effects dealt with, but they are in most cases in approximate agreement with the experimental data, although the scales marked on the loss curves are rather a matter of guidance than of fact.

PETROL CONSUMPTION OF THE "AIRCO 18" AEROPLANE.

TO THE EDITOR OF ENGINEERING.

SIR,—With reference to the description in your issue of August 20 of the "Airco 18" aeroplane, we notice the statement that the petrol consumption of the Napier engine fitted to this machine is 32 gallons per hour. This figure is an extraordinarily high one, and one which could only be reached by running at very high power. As a matter of fact the actual petrol consumption of the Napier engine in an aeroplane of the type described averages about 25 gallons per hour in service, and we think, therefore, that some mistake has arisen in connection with your notes. I should be glad if you will kindly rectify same in your next issue.

Yours truly,
H. T. VANE
(D. NAPIER AND SON, LIMITED),
Managing Director.

14, New Burlington-street, London, W.,
August 24, 1920.

[NOTE.—In connection with the above letter from Messrs. Napier we should explain that the petrol consumption given on page 238 *ante* for the Napier engine in the "Airco 18," viz., 32 gallons per hour, is that obtained with the engine "all out," in which condition it would develop about 500 h.p. and give the machine a flying speed of 121 m.p.h. On the Paris service, in which the engine is throttled down to give a flying speed of about 100 m.p.h., we are informed by the designer that the petrol consumption is rather less than that mentioned above by Messrs. Napier, averaging from 23 gallons to 24 gallons per hour. In describing the Napier engine at the recent Aero Exhibition, on page 106 *ante*, we gave the consumption at 0·48 lb. per brake horse-power hour at full load, a figure which was supplied to us by Messrs. Napier themselves. This gives a total consumption of 210 lb. per hour, and, taking the specific gravity of petrol as 0·72, works out at 30 gallons per hour.—ED. E.]

THE FIRST HEROULT ELECTRIC STEEL FURNACE.

TO THE EDITOR OF ENGINEERING.

SIR,—We notice that in their letter appearing in your issue of August 13, Messrs. Edgar Allen and Co. take exception to Mr. Dunderdale's statement that the electric steel furnace installed by us before the war, was the first in this country.

They are right in their statement as far as it goes, but as Mr. Dunderdale's paper dealt with furnaces used for the production of steel castings, and as Messrs. Edgar Allen's furnace was not, we believe, used exclusively or extensively for this purpose, we think this should have been mentioned to avoid conveying a wrong impression.

To the best of our knowledge the Heroult Furnace started by us in December, 1910, was the first electric furnace installed in Great Britain solely for the production of steel castings, and the Snyder Furnace started by the National Steel Foundry in 1915 was the first in Scotland.

Yours faithfully,
(*pro* LAKE AND ELLIOT, LIMITED)
W. B. LAKE,
Managing Director.

ITALIAN MOTOR SHIPS.—Italian shipowners, having been seriously hampered by the rise in prices of bunker coal at Italian ports, have turned their attention to oil fuel vessels and motor ships, says *The Marine Journal*, New York. The first of a series of five 8,100-ton motor vessels built for the Societa Nazionale di Navigazione proved so successful on the route between Genoa and South American ports that the owners having since received the remaining four vessels, have placed orders for six motor ships of much larger size. These, in addition to cargo carrying capacity of 12,000 tons each, will have accommodation for a limited number of passengers. They will be placed on the South American service.

THE ENGINEERING TRAINING ORGANISATION.

THIS organisation, which was founded on October 25, 1917, on a resolution proposed by the late Sir John Wolfe-Barry, was brought to a close at a meeting of the council which was held at the Institution of Civil Engineers on Wednesday last. The chair was taken by Sir Maurice Fitzmaurice, C.M.G., who was supported by Mr. C. H. Wordingham, Sir William H. Ellis and the secretary, Mr. A. E. Berriman, chief engineer of the Daimler Company. Sir Maurice Fitzmaurice stated that since the organisation had been founded, three years ago, a very large amount of work had been carried out, first under the guidance of Sir W. H. Ellis, then under that of Mr. Wordingham, the greater part of the said work having been done by Mr. Berriman. In the earlier period he did not anticipate that great progress would be made by the scheme, but he fully expected that later on greater enthusiasm would have been shown towards it than had actually been the case. They first asked technical institutions and societies to help with grants of funds and three replied favourably. Their contributions, however, were insufficient for the work, and they applied to engineering firms; but these did not respond favourably. The organisation, therefore, had not sufficient funds to carry on; in fact, it may be said that it never had funds in hand. Notwithstanding this, the organisation had gathered together a very large amount of information and statistics, and had also helped quite a number of young men to start with engineering firms; it would be a great pity if the work done were lost.

Mr. Wordingham confirmed the statements made by the chairman and added that the council felt that their work should be carried on. It could be transferred to one of two existing bodies, either the Employers' Federation, or the Federation of British Industries.

Sir William H. Ellis also confirmed the situation and added that owing to the war the works throughout the country had been actually blocked up with applications from apprentices, a fact which entirely altered the aspect of things. The firms had their own lists to select from. But the result of the work of the organisation had been to bring into existence a history of apprenticeship and a record of the state of matters in the country, both of which, he felt sure, would be certain to meet with the gratefulness of the body which would ultimately carry on the organisation's work.

The following resolutions were then moved by Mr. Wordingham, and were carried unanimously: "That the executive committee confer with the two bodies above named, asking that one or the other continue the work." "That in the event of an agreement the secretary to hand over to the body accepting the work done and the cash balance if any, and the organisation to cease to exist from that date." The meeting terminated by a vote of thanks to Mr. Berriman for the work he had done in the matter, the facilities granted by the Daimler works being also duly acknowledged.

THE PEAT RESOURCES OF SWEDEN.—According to estimates worked out by the Peat Committee, and referred to in *Swedish Export*, the supplies of peat in Svealand and Götaland—not including Norrland, whose peat areas are not considered to be equally accessible for commercial purposes—amount to about 1,250,000,000 tons of air-dried combustible peat, equal to about 625,000,000 tons of coal having a calorific value of about 7,000 calories. This figure is considered too low an estimate rather than too high, and comprises only such deposits as contain combustible fuel alone or combustible fuel to a predominant extent. In this connection the committee further states that the total output of combustible peat, which in 1915 was estimated at about 90,000 tons, increased uninterruptedly during the following years, so that in 1918 it amounted to about 450,000 tons in spite of unfavourable conditions. In 1919, 350,000 tons to 400,000 tons were raised.

THE LATE MR. JOHN TAYLOR.—We regret to have to record the death, which occurred on August 24, at his residence, The Priory, Weston, Bath, of Mr. John Taylor, who had been for many years head of the firm of John Taylor and Sons, 6, Queen-street-place, E.C. Mr. Taylor was a member of the Institution of Civil Engineers since 1884, a member of the Institution of Mining and Metallurgy, and a Fellow of the Geological Society. Mr. Taylor was born in 1841 and was educated at Hove School, Brighton, and at University College, London. He then studied mining in Wales and in Devonshire, and in 1861 he took the local management of mines in those districts. He went to Canada in 1868 to visit Canadian mines, and then travelled to the United States, Spain and Portugal for a similar purpose. He became a partner, in 1871, in the firm of John Taylor and Sons, which at that time consisted of his father and his uncle. He became the senior partner in the firm in 1883 and retired from active business in 1903.

PARTITION OF THE LOAD IN RIVETED JOINTS.*

By Dr. C. BATHO, McGill University, Montreal.

A RIVETED joint may be regarded as a statically indeterminate structure and a series of equations may be obtained for any joint by means of the principle of Least Work, giving the loads carried by each of the rivets in terms of a quantity K, which depends upon the manner in which work is stored in, or by the action of the rivets. This method has been applied to various type of joints and the modifying effects of non-uniform distribution of stress in the plates, unequal partition of load between the two cover plates and a difference in the modulus of elasticity of the cover plates and middle plate have also been considered. The theory has been verified experimentally by extensometer measurements on the outer surfaces of the cover plates of a number of double cover butt joints. The validity of this method of experiment was first determined by experimenting on a specimen in which the middle plate was made wider than the outer plates so that extensometer measurements were possible on the middle plate as well as on the cover plate. This experiment showed that the mean stresses in the cover plates could be determined from the strains on their outer surfaces. It was also shown that, at any rate after the first few loadings, the distribution of strain in the plates of the joint is not altered by repeated loadings. Experiments made on a number of specimens having a single line of rivets, and loaded in tension, gave results in close agreement with the theoretical considerations. They also showed that the longitudinal stresses in a portion of the cover plate between two consecutive rivets are a maximum at the edges of the plates falling to a minimum along the line of rivets. The value of K for a joint having a given ratio of width of cover plate to rivet pitch was found to vary directly as the load and inversely as the area of cross-section of the rivets. An empirical rule was determined for its value in joints similar to the experimental specimens, but a general rule cannot be given until further experiments have been made. A theoretical estimate of the value of K for a rivet acting in shear gave results within the range of the experimental values. This fact, the validity test, and the general manner of longitudinal distribution of strain, all seemed to show that the rivets were acting in shear rather than by friction.

Both the experimental results and the theoretical deductions show that in a double-cover butt joint having a single line of rivets, the two end rivets and the two rivets on each side of the junction of the middle plates take by far the greater proportion of the load at all loads within that causing permanent deformation of the plates or rivets, the actual proportion decreasing slowly as the load increases. If the total area of cross-section of the cover plates is equal to that of the middle plates these four rivets take equal loads; if it is greater, the end rivets take greater loads than the others and if it is less the rivets on each side of the junction take greater loads than the end rivets. Members riveted to a gusset plate increasing in width from the first to the last rivets show a rather more uniform distribution. Most of the results given are discussed fully in a paper by the author, published in the Journal of the Franklin Institute (U.S.A.) in November, 1916.

The results already obtained allow the general manner of partition of the load in any riveted joint, in which there is no eccentricity of connection, to be estimated, and it is hoped that, when further experiments have given general laws for the value of K, it will be possible to predetermine exactly the load carried by each rivet.

PERSONAL.—Mr. H. Parsons, the managing director of the Parsons Motor Company, Limited, Southampton, informs us that he is leaving England on the 6th inst. for Canada and the United States, and expects to be away about a couple of months. One of the objects of his visit is to attend the Ninth Congress of Chambers of Commerce of the British Empire at Toronto in September, and thereafter to continue the visit in Canada and the United States in connection with various business and other interests.

MECHANICAL APPLIANCES IN MALAYA.—In view of the difficulties connected with the scarcity of labour and food shortage on most planting and mining propositions in Malaya, attention is being directed more and more to mechanical means to make up for these deficiencies, says *The London and China Telegraph*. Tractors of all sorts and sizes are now being extensively used for agricultural operations, and where the ground is suitable they should be of great assistance and economy, whether for purposes of opening and development or for the subsequent upkeep, for weeding or cultivation. These machines have been well reported on, and have generally given considerable satisfaction, and at the same time have been most economical as against the work of coolies. In like manner motor traction is growing as an efficient aid of the planting community. Not long since the American Consul at Medan, Sumatra, reported that motor trucks are showing their superiority over the old bullock cart. This may well be appreciated, and as the roads of the estates are being put in better condition, trucks can readily be used to transport the crops to the railroads, but it is not believed that they would be found practicable for the longer runs. Between the tractor and the trolley there may well be considerable economy, as well as assistance, in these days of scarce and dear labour and rice shortage.

*Abstract of paper read before Section G, at the Cardiff meeting of the British Association, August 25, 1920.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—The position in the Scotch steel trade shows little variation, and just how the new conditions through the increase in railway rates will affect business is rather uncertain. Buyers have not been placing fresh orders of late, but order books all round are still well filled and there is no cause for alarm as regards the immediate future. The outlook for the early part of next year is not so promising, but the steelmakers are not pessimistic. Ship plates are in steady demand and the good shipbuilding returns of the past month show that deliveries have been very satisfactory, although yards could have taken more. Boiler plates have also been very active, but structural sections have been somewhat easier. In the black sheet trade the conditions are practically unaltered and the whole of the present large output is going rapidly into consumption. Galvanised sheets are also fairly strong, and some satisfactory lines have lately been fixed up. While the home trade has been absorbing the bulk of all classes of steel material for a considerable time back, and there has been very little going abroad, signs are not wanting that an opening out may take place in this direction before many months are past.

Malleable Iron Trade.—The demand for bar iron is still on a very large scale, and all the works in the West of Scotland are fully employed. Makers have a large tonnage booked, sufficient to cover the total output for some months yet, but the export trade shows signs of reviving, and as soon as any material is available the foreign consumer will receive more consideration.

Scotch Pig-Iron Trade.—The pressure for Scotch pig-iron continues heavy, but the outlook is not so promising owing to the attitude of the miners, and if a strike does take place all the industries of the country will be disorganised. When the demand for iron is so urgent a strike would be most unfortunate, and the Scotch ironmasters are hopeful that this will be averted. The increased railway rates will be found bad enough at present without further trouble being put in the way of industry, and the heavy rates now necessary for long distances will considerably reduce the amount of iron sent south. This will most probably be met by exporting. The available supplies of foundry iron are being quickly taken up, and this grade of iron is still very scarce, and so also is hematite. For the latter the steelmakers keep up a constant demand. The supply of forge iron is better at the moment, and this grade is more easily obtainable. Prices are not being altered meantime as the higher railway rates are counterbalanced by inward ore being easier.

Scotch Shipbuilding Trade.—The past month has been an exceptionally good one in the shipbuilding trade of Scotland in the matter of new tonnage which is not far short of the large output of April. The following are the totals for the different districts :—

	Vessels.	Tons.
The Clyde	27	87,912
The Forth	3	4,591
The Tay	—	—
The Dee and Moray Firth...	7	4,112
Total	37	96,615

These figures bring the total Scotch output for the year to date to 204 vessels, aggregating 497,679 tons. The Clyde portion of that total is 142 vessels of 440,174 tons, which now constitutes a record for the first eight months of any year. The previous best was thirteen years ago when the totals were 239 vessels amounting to 421,083 tons, and this year is thus 19,091 tons higher than 1907, and it is also 29,393 tons above the total for the eight months of 1913, which was finally the record year of the industry on the Clyde. The prospects of this year ultimately creating a new record output are a shade doubtful because of labour troubles and the probability of a strike of miners backed up by the other members of the triple alliance. There is plenty of work on hand to keep the different yards busy for a considerable time, but the enormous cost of new vessels now has frightened owners and orders have been conspicuous by their absence during the past month or two. Until more reasonable prices rule there is little prospect of shipowning firms entering the market, and the shipbuilding output for next year is far from bright at present.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Electricians' Dispute.—Locally there is no development in the electricians' dispute, which threatens to dislocate a large section of the engineering industry, following the employment of a non-union foreman at the Penistone works of Messrs. Cammell Laird and Co., Limited. Lock-out notices served on members of the Electrical Trade Union expire on Saturday. The only hopes of a settlement in the interim lie in the intervention of the Ministry of Labour.

Iron and Steel.—With the industrial position overshadowed by the coal crisis, business generally is on a small scale. Buyers at home and overseas are apparently awaiting some definite development before proceeding with forward bookings. A significant feature is the decision of steel makers to reduce the price of basic billets from 1*l.* to 2*l.* per ton. This is to some extent due to the increased tonnage of foreign material arriving in this district, but is more largely attributed to the diminution in purchases by the manufacturing sections during the last six weeks. There is still, however, a marked shortage of hoops, sheets and bars. Current quotations are as follow : Siemens acid billets, 28*l.* 15*s.* ; Bessemer billets, 28*l.* 5*s.* ; hard basic billets, 25*l.* 10*s.* ; soft basic billets, 23*l.* 10*s.* ; "Crown" bars, 30*l.* ; iron hoops, 36*l.* 2*s.* 6*d.* ; steel hoops, 36*l.* ; steel sheets, 52*l.* ; Derbyshire No. 3 foundry, 14*l.* 7*s.* 6*d.* ; Derbyshire forge, 12*l.* 10*s.* ; Lincolnshire basic, 14*l.* ; Lincolnshire foundry, 14*l.* 5*s.* ; West Coast hematite mixed numbers, 15*l.* 5*s.* ; East Coast hematite mixed numbers, 13*l.* 10*s.* ; all delivered in Sheffield. Steel scrap seems plentiful at 10*l.* to 11*l.* per ton, and there is a larger tonnage of steel turnings available for purchase. Makers of electric steel are getting towards the end of order books, and as a precautionary measure are distributing work over three to four days a week. The rolling mills have got back to normal conditions. There is plenty of work to keep the foundries fully occupied. Trade in steel-making alloys is distinctly easier, following a marked decline in purchases of high-speed steels. The question is being asked in some quarters whether the boom in implements and hand tools is not nearing the end. This may be so as regards twist drills. But pressure for joiners' and edge tools is still great, and many of the largest file-making concerns have as much as they can do to keep pace with requirements.

South Yorkshire Coal Trade.—Considerable doubt is displayed among a big section of the mining industry in this district as to whether the bulk of the South Yorkshire miners would "down tools" even if a national strike was ordered by the Miners' Federation. The Yorkshire ballot has not produced anything like a two-thirds majority for extreme action. The fact is also emphasised that the funds of the Yorkshire Miners' Association, following the recent county dispute, are not in a fit state to bear the strain of a general stoppage. Meanwhile, there is a tremendous pressure for all classes of fuel. Buyers are anxious to build up reserves, and have also been rushing orders through, in the hope of avoiding the advanced rates. Depôts to-day are charging 2*s.* 2*d.* per ton extra to cover increased railway charges for carriage and wagon hire, but this, of course, does not affect the quotations at the pits. The current demand for house coal is greater than merchants can deal with. Notices have been issued restricting deliveries to one load at a time so that supplies may be evenly distributed. Contractors are pressing collieries to maintain supplies of best steams and fine slacks, in view of the present unsettled condition of affairs. Cobbles and nuts occupy a strong position. Cokes of all descriptions are difficult to obtain. Quotations :—Best branch handpicked, 37*s.* 2*d.* to 38*s.* 2*d.* ; Barnsley best Silkstone, 37*s.* 2*d.* to 37*s.* 8*d.* ; Derbyshire best brights, 35*s.* 2*d.* to 36*s.* 2*d.* ; Derbyshire house coal, 32*s.* 8*d.* to 33*s.* 2*d.* ; Derbyshire best large nuts, 32*s.* 8*d.* to 33*s.* 8*d.* ; Derbyshire small nuts, 31*s.* 8*d.* to 32*s.* 8*d.* ; Yorkshire hards, 32*s.* 8*d.* to 33*s.* 8*d.* ; Derbyshire hards, 32*s.* 8*d.* to 33*s.* 8*d.* ; rough slacks, 28*s.* 2*d.* to 29*s.* 2*d.* ; nutty, 27*s.* 2*d.* to 28*s.* 2*d.* ; smalls, 23*s.* 2*d.* to 24*s.* 2*d.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—The market is steady and firm. Consumers of Cleveland pig-iron do not hesitate to follow the 7*s.* 6*d.* advance made to cover extra charges due to heavier railway rates. The rise is considered quite a just one, and one not likely to more than cover the greater expense of assembling raw material at the furnaces. Considerable complaint is heard of delay in deliveries of coke, ironstone and limestone because of inadequate truck supply. It is still impossible to purchase Cleveland foundry pig-iron for abroad, makers adhering to their decisions not to sell for export so long as home needs cannot be fully met. For home consumption, No. 3 and the lower qualities of Cleveland pig-iron are 225*s.*, and No. 1 is 237*s.* 6*d.*

Hematite Iron.—A moderate business is passing in hematite iron, foreign demand showing some improvement. Most makers are not seeking orders, as they are very well booked up, but merchants are able to offer substantial parcels. To home customers, Nos. 1, 2 and 3 East Coast brands are 260*s.*, and No. 2 is 262*s.* 6*d.*; whilst for despatch to France, Belgium and Italy mixed Nos. are 265*s.* and No. 1 is 267*s.* 6*d.*

Foreign Ore.—Buyers and sellers of foreign ore are gradually coming together, but as yet there is not much business passing. A few transactions, however, have been put through at equal to 47*s.* 6*d.* ex-ship Tees for rubio of 50 per cent. quality. The freight, Bilbao-Middlesbrough stands at 17*s.* 6*d.*

Coke.—Coke is strong, and not over plentiful. Average blast-furnace kind is 62*s.* 9*d.* at the ovens, and quality low in phosphorus is 65*s.* 3*d.* at the ovens.

Manufactured Iron and Steel.—There is a quiet feeling in finished iron and steel, and in some branches customers are holding back in the hope of being able to place orders on more advantageous terms than are now named. The volume of new trade as regards railway material is disappointing. Common iron bars are 30*l.* ; marked bars, 32*l.* ; iron ship angles, 30*l.* 15*s.* ; channels and flats, 23*l.* 5*s.* ; rounds and squares, 25*l.* 10*s.* ; steel ship, bridge and tank plates, 23*l.* 10*s.* ; steel ship angles, 23*l.* ; steel boiler plates, 30*l.* ; steel joists, 23*l.* ; soft steel billets, 25*l.* 10*s.* ; hard steel billets, 26*l.* 10*s.* ; heavy sections of steel rails, 25*l.* 10*s.* ; fish plates, 30*l.* ; black sheets, 39*l.* ; and corrugated galvanised sheets, 47*l.*

Shipments of Iron and Steel.—Shipments of iron and steel from the port of Middlesbrough last month totalled 57,516 tons, as compared with 89,909 tons for July. Of the August clearances, 28,252 tons were pig-iron, 18,618 tons were manufactured iron, and 10,646 tons were steel. Of the pig-iron despatched 23,277 tons went to coastwise customers, and 4,975 tons went to foreign ports, the principal receivers being Scotland, 17,879 tons ; the Tyne, 3,840 tons ; Belgium, 2,170 tons ; and Germany, 1,303 tons. Only 456 tons of manufactured iron went coastwise ; whilst 18,162 tons went abroad, India, with an import of 12,872 tons being by far the best customer, Natal coming next with 2,699 tons. Of the steel loaded 1,181 tons went coastwise and 9,485 tons went to foreign destinations, the largest being China, 1,917 tons ; Japan, 1,671 tons ; India, 1,153 tons ; Belgium, 1,006 tons ; and Egypt, 1,001 tons.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—The threatened strike of coal miners throughout the country has completely disorganised business on the coal market. The official ballot results show a big minority vote, and in some quarters this fact is responsible for a feeling that the miners' leaders will not go to the length of a strike in face of the fact that in this ballot the miners were specifically recommended to vote for a strike. It is contended that such a large minority vote is a warning to the leaders that a very large section of the miners are evidently realising that they are not acting in their own interests in bringing about stoppages. Meanwhile new business is rendered almost impossible, for with reduced outputs collieries have in many cases not sufficient coal to meet their contract commitments, and the probability is that even less will be available on the open market in future as collieries have received instructions that at least 50 per cent. of arrears shall be eventually delivered. Releases for all destinations are sparingly granted and this further aggravates the difficulties of buyers. The South Wales coalowners have agreed voluntarily to continue to supply foreign-going vessels with their bunker requirements at fixed prices of 80*s.* per ton f.o.b. for large, 75*s.* for through, and 60*s.* for smalls, while in respect to bunkers for home coasters the Mines Department of the Board of Trade have cancelled the maximum f.o.b. prices order of November, 1919, and substituted pithead prices, which are 23*s.* 2*d.* per ton in excess of the 1914 price. Shipowners are not yet clear whether the new prices mean a financial benefit or not for the increased railway rates and tipping charges have to be added to the maximum prices. Owners of foreign-going vessels are reaping a definite advantage, for the increased railway rates will be borne by the colliery companies.

Loss of a Swansea Steamer.—An important Board of Trade inquiry was opened at Cardiff yesterday before Sir W. T. Lewis, who was assisted by nautical and engineering assessors. The inquiry is into the circumstances of the loss of the Swansea-owned steamer Glendalough. According to the opening statement of Mr. Daniel Stephens, K.C., for the Board of Trade, the Glendalough, a wooden steamer of 179 tons net, was purchased by Mr. W. J. Jones, of Swansea, in February last, for 19,000*l.* She was subsequently loaded with a cargo of wood blocks in Greenwich, and proceeded to an Irish port. On March 25 she stranded at Ballyquentin Point and was smashed up, the crew swimming ashore. The alleged cause of the stranding was the jamming of the steering gear at a critical moment. The vessel and freight, said counsel, was insured for a total of 61,800*l.*, of which freight amounted to 31,200*l.*, though the freight was paid for in advance on this voyage, and therefore the owner had no insurable interest. In conclusion, counsel said as far as they could see, this ship, which cost 19,000*l.*, was insured on this venture, which resulted in her loss, for a figure of 61,800*l.* There were two witnesses he would call, and if their evidence was true, there was something requiring an explanation apart from excessive insurance.

SOUTH AFRICA : SUPPLIES OF RAILWAY MATERIAL.—The Union Parliament has sanctioned an agreement whereby the Government Railways will draw from the Pretoria iron mining companies about half of their requirements in railway materials of local manufacture at a price which compares with the lowest c.i.f. foreign quotation. The first delivery is to be made at the beginning of the year 1923. The contract expires in 1937.

THE LONDON IRON AND STEEL EXCHANGE, LIMITED.—For the moment the iron and steel trades of the country are in a state of suspense, and until the outcome of the miners' agitation is apparent there is little prospect of an improvement. Neither manufacturers nor merchants are inclined to enter into commitments with the threat of a coal strike hanging over their heads. The export trade has dwindled to small proportions and anxiety has been occasioned by the numerous cancellations of material by eastern trades, who, a few months ago were recklessly buying regardless of price. This action has reacted upon the home market. The future of the market seems to depend entirely upon financial developments and the attitude of labour. If once the confidence which has been ruddy disturbed by the recent actions of labour is restored it is generally believed that the iron and steel markets will show an immediate response, and it is not unlikely that it would also be reflected in an improvement in financial conditions. German galvanised sheets have been offered in London recently. Belgian works are badly off for orders and seem ready to cut prices to keep their works going. At the moment a feature of the situation is the cheap offering of semi-finished material from the Continent.

THE MACHINE TOOL AND ENGINEERING EXHIBITION AT OLYMPIA.

(*For Description, see Page* 301.)

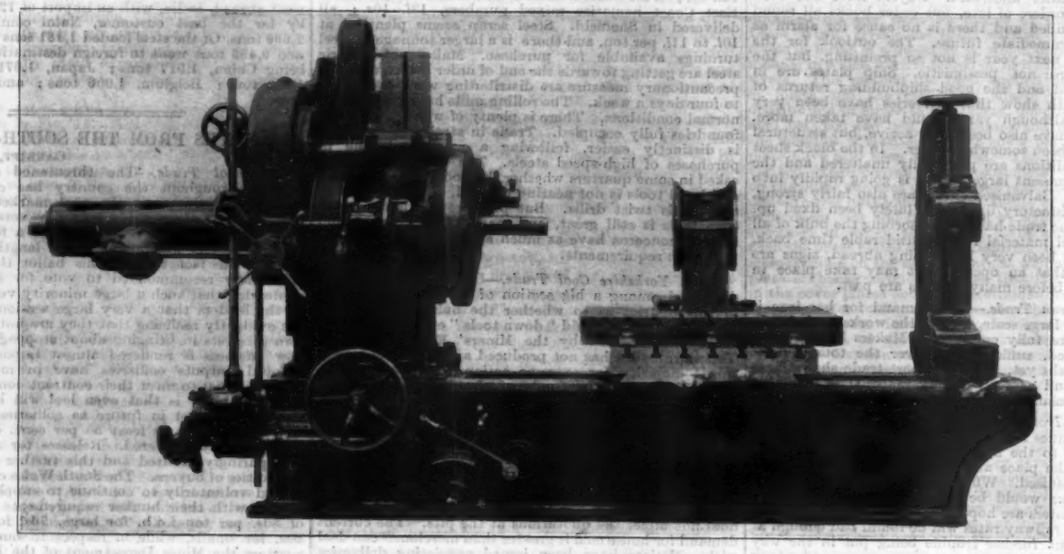


FIG. 50.

Fig. 51.

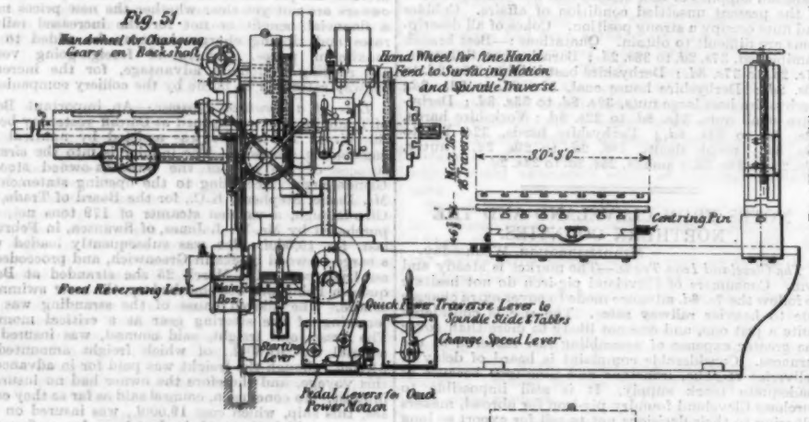

Handwheel for Changing Gears on Backshaft
Hand Wheel for fine Hand Feed to Surfacing Motion and Spindle Traverse
Max 26" at Traverse
5'0"-5'0"
Centring Pin
Feed Reversing Lever
Main Box
Quick Power Traverse Lever to Spindle Slide & Table
Starting Lever
Change Speed Lever
Pedal Levers for Quick Power Motion

Fig. 52.

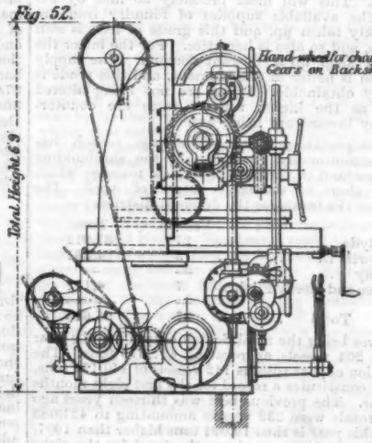
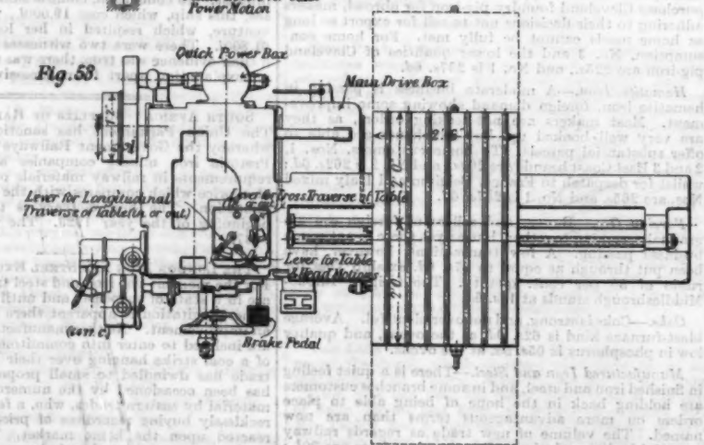


Fig. 53.


Quick Power Box
Main Drive Box
Lever for Longitudinal Traverse of Table (in or out)
Lever for Cross Traverse of Table
Lever for Table & Head Motions
Brake Pedal

AUSTRALIAN COAL FOR SWEDEN.—According to statements made in the Press, says *Swedish Export*, contracts have been concluded for the sale of 140,000 tons of steam screened Australian coal to be delivered in Sweden during the second half of 1920. It is expected that further contracts will be concluded for 100,000 tons. The coal-exporting conditions in Australia are said at the present time to be such that Sweden could without difficulty obtain as much as 500,000 tons. The price of the coal delivered in Sweden will be 182*s.* 6*d.* to 192*s.* 6*d.* per ton, while British steam coal on delivery at Gothenburg commands as high a price as 223*s.*

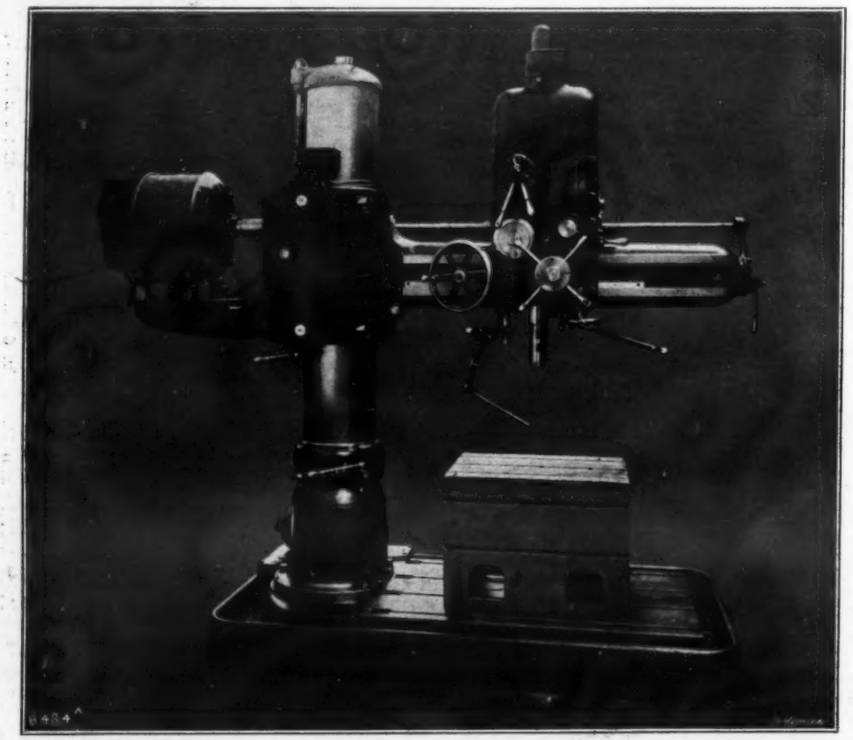
FUELING AT TAHITI.—The French possession of Tahiti, in the South Pacific, is soon to become one of the world's largest fuel oil stations according to *The Marine Journal*, New York. The construction of three large tanks capable of storing thousands of barrels of oil is under way, under the shipping and trading policy of the French Government. The station is being erected primarily for the use of vessels operating from San Francisco and Vancouver to Australia and New Zealand, but vessels on the run from Australia to New York, France, Great Britain and Italy, by way of the Panama Canal, will also be served.

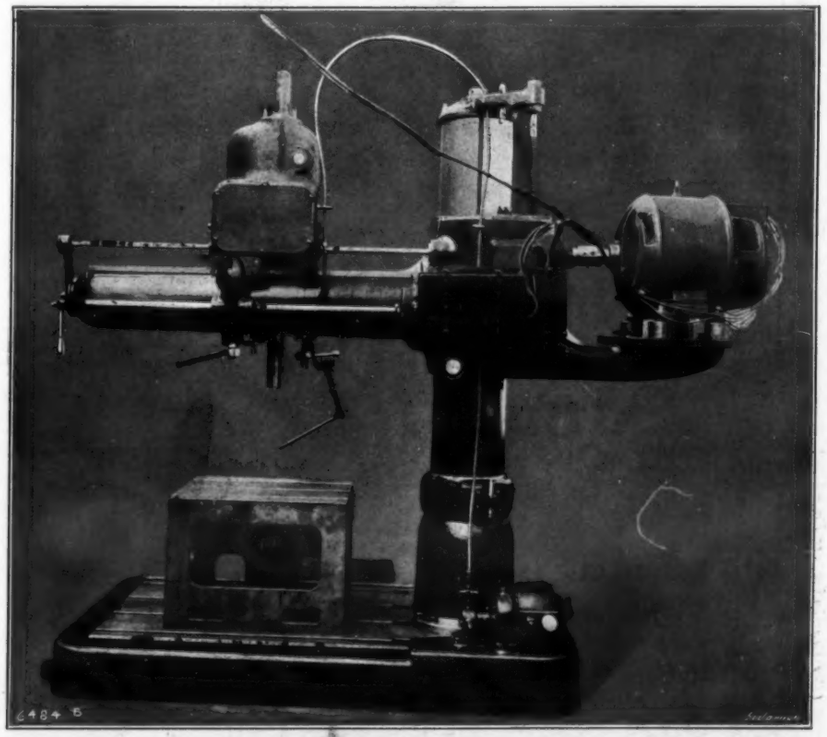
THE FOREIGN POPULATION OF CHINA.—A table attached to the annual report of the Chinese Maritime Customs for 1919, says *The London and China Telegraph*, shows that the foreign population of China amounted to 351,000 in all. The largest number of any nationality is of the Japanese, with 4,878 firms and 171,485 individuals. Russia follows with 1,760 firms and 148,170 persons, then Britain (644 firms and 13,234 persons), America, (314 firms and 6,660 persons), France (171 firms and 4,409 persons, including 918 *protégés*), Portugal (93 firms and 2,390 persons), Denmark (27 firms and 546 persons), Belgium (20 firms and 391 Nationals), Italy (19 firms and 276 persons), and Norway (12 firms and 249 persons). The other nationalities show only very insignificant numbers, except Germany, which has 2 firms and 1,335 Nationals, whilst her ally, Austria, has 5 firms, but only 27 individuals.

BRANNERITE, A NEW URANIUM MINERAL.—In 1915 a new, highly radio-active mineral was found in some pegmatite and granite of gold placers in Idaho. The mineral in question, brannerite, occurs in grains of about pea size, apparently prismatic though too irregular for crystal measurements; it is black but of a yellowish-green translucency. The examination by Frank L. Hess and Roger C. Wells (*Journal of the Franklin Institute*, February, 1920) show that brannerite, is practically a metatitanate of uranium, thorium, yttrium, &c., containing about 4 per cent. of thoria and 44 per cent. of uranium as dioxide and trioxide; this percentage makes brannerite the richest uranium mineral next to pitchblende. It was, therefore, very surprising that the mineral did not appear to contain any helium. When the spectroscopic search for helium was repeated by a different method, the yellow helium lines were observed; in the new tests the gases liberated by fusing the mineral with sodium bisulphate were first purified by means of charcoal and liquid air.

THE MACHINE TOOL AND ENGINEERING EXHIBITION AT OLYMPIA.

(*For Description, see Page* 301.)





FIGS. 4 AND 5. FRONT AND BACK VIEWS OF 4 FT. RADIAL DRILL; MESSRS. ALFRED HERBERT, LTD.

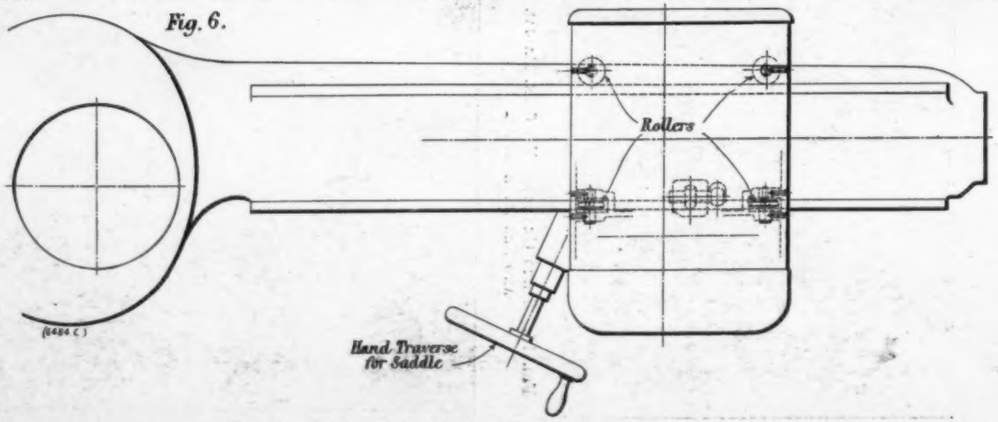


FIG. 6. ARM OF 4 FT. RADIAL DRILL.

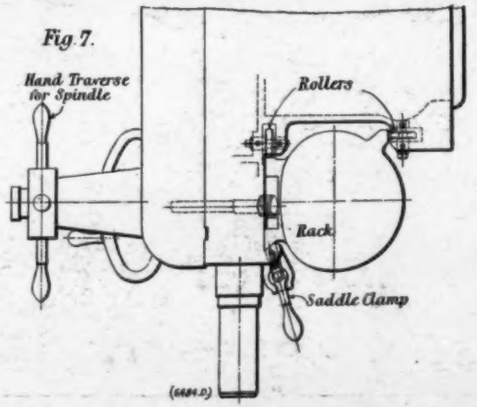


FIG. 7. SADDLE OF 4 FT. RADIAL DRILL.

(*To face page* 302.)

THE MACHINE TOOL AND ENGINEERING EXHIBITION AT OLYMPIA.

(*For Description, see Page* 301.)

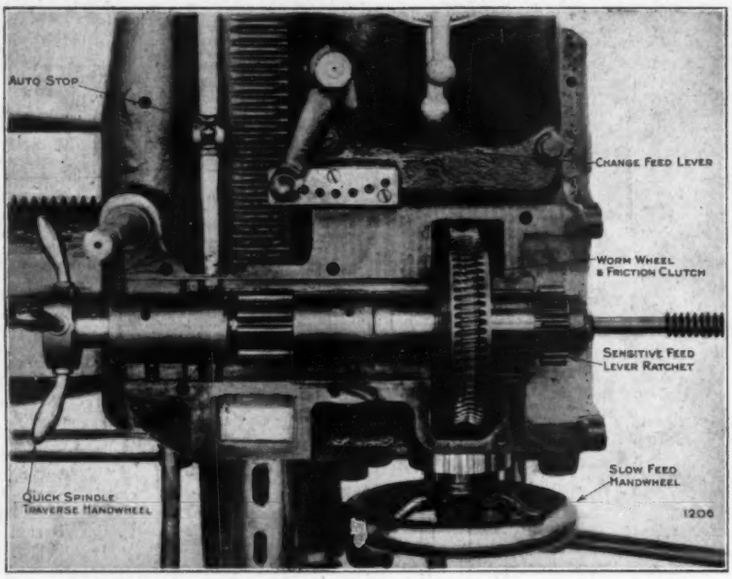


FIG. 8. FEED, SPINDLE OF 3 FT. 6 IN. RADIAL AND SENSITIVE DRILL.

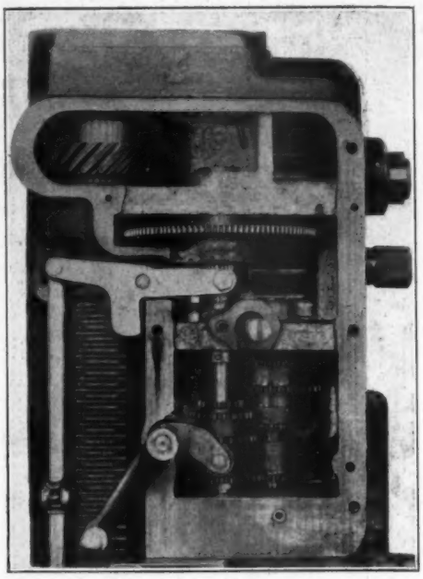


FIG. 9. FEED GEARS OF 3 FT. 6 IN. RADIAL AND SENSITIVE DRILL.

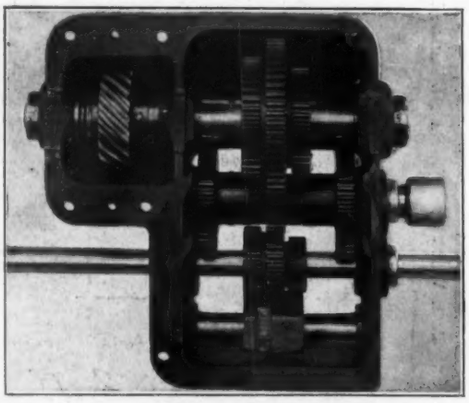


FIG. 10. SPEED GEARS; 3 FT. 6 IN. RADIAL AND SENSITIVE DRILL.

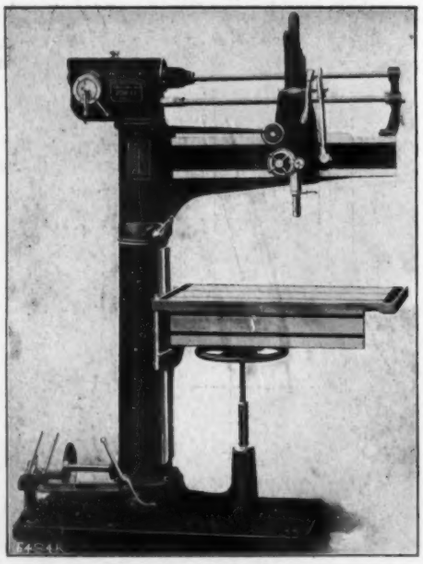


FIG. 12. 32-IN. RADIAL SENSITIVE DRILL; MESSRS. JAMES ARCHDALE AND CO., LTD.

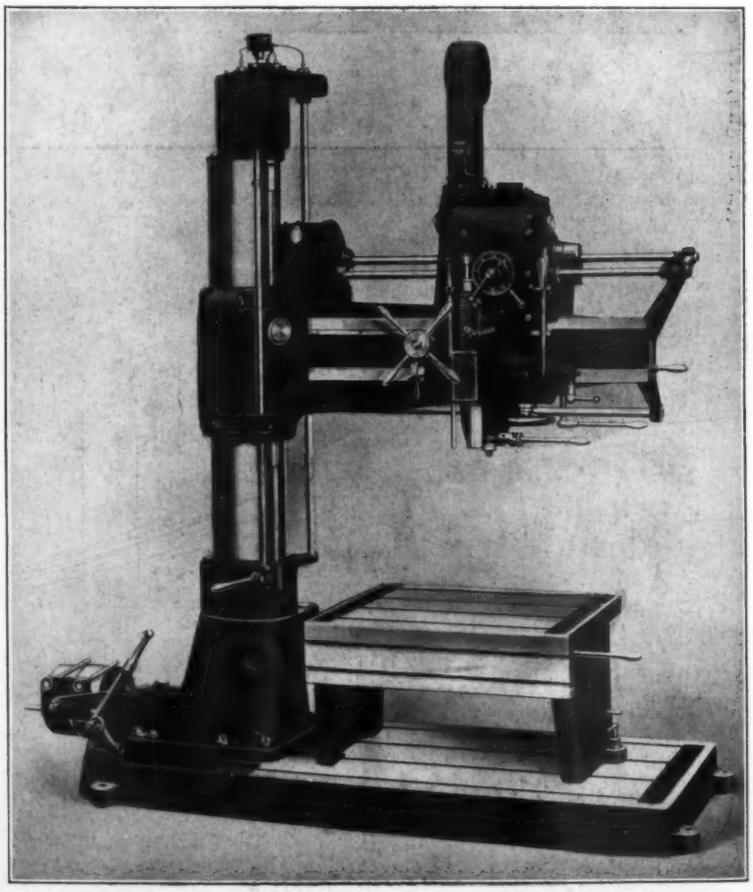


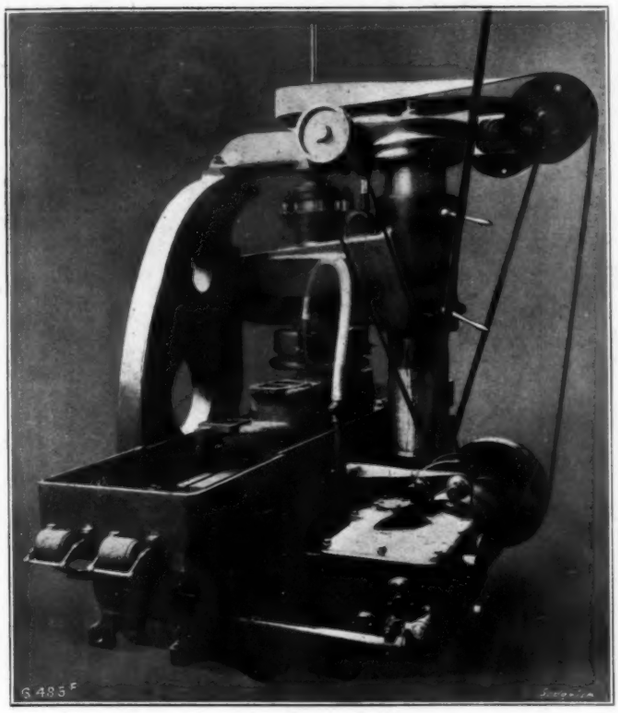
FIG. 11.

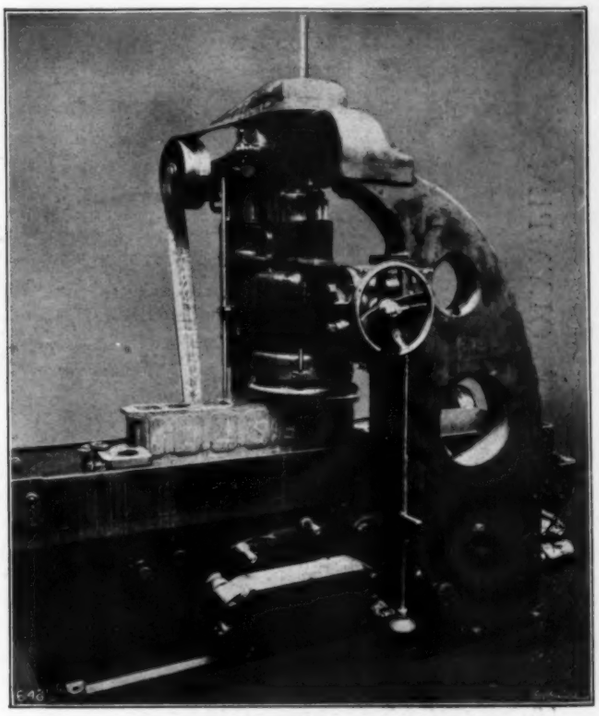
FIGS. 8, 9, 10 AND 11. 3 FT. 6 IN. RADIAL AND SENSITIVE DRILL; MESSRS. JAMES ARCHDALE AND CO., LTD.

(*To face page* 303.)

THE MACHINE TOOL AND ENGINEERING EXHIBITION AT OLYMPIA.

(*For Description, see Page* 301.)





FIGS. 15 AND 16. FRONT AND BACK VIEWS OF VERTICAL SURFACE GRINDER; MESSRS. THE LUMSDEN MACHINE CO., LTD.

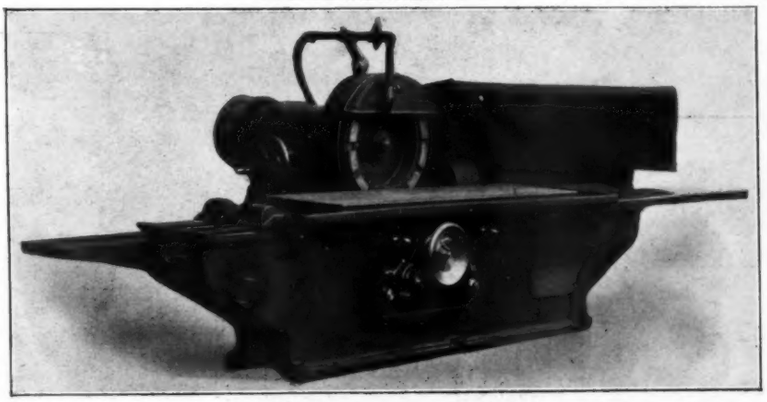


FIG. 17. HORIZONTAL SURFACE GRINDER; MESSRS. THE LUMSDEN MACHINE CO., LTD.

FIG. 19.

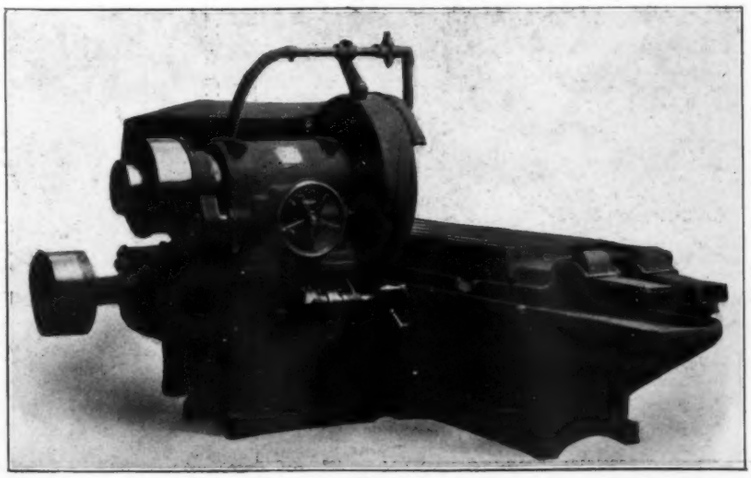


FIG. 18. HORIZONTAL SURFACE GRINDER; MESSRS. THE LUMSDEN MACHINE CO., LTD.

FIGS. 19 AND 20. GAUGE AND FORM TOOL GRINDER; THE LUMSDEN MACHINE CO., LTD.

(*To face page* 304.)

THE MACHINE TOOL AND ENGINEERING EXHIBITION AT OLYMPIA.

(*For Description, see Page* 301.)

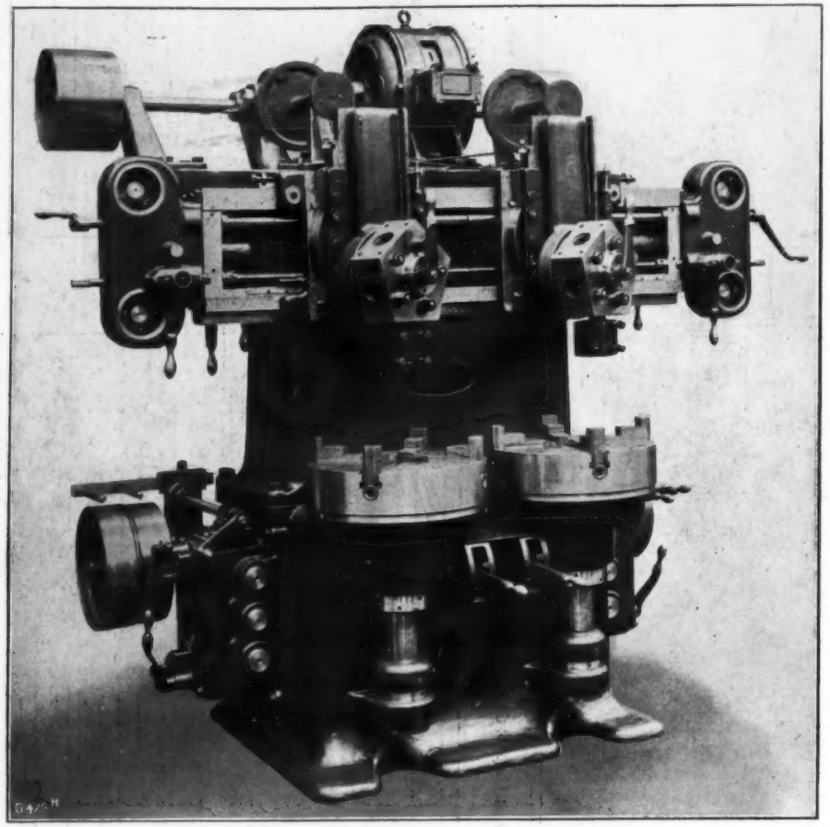


Fig. 21. 20-In. Duplex Boring Mill; Messrs. G. Wilkinson and Sons.

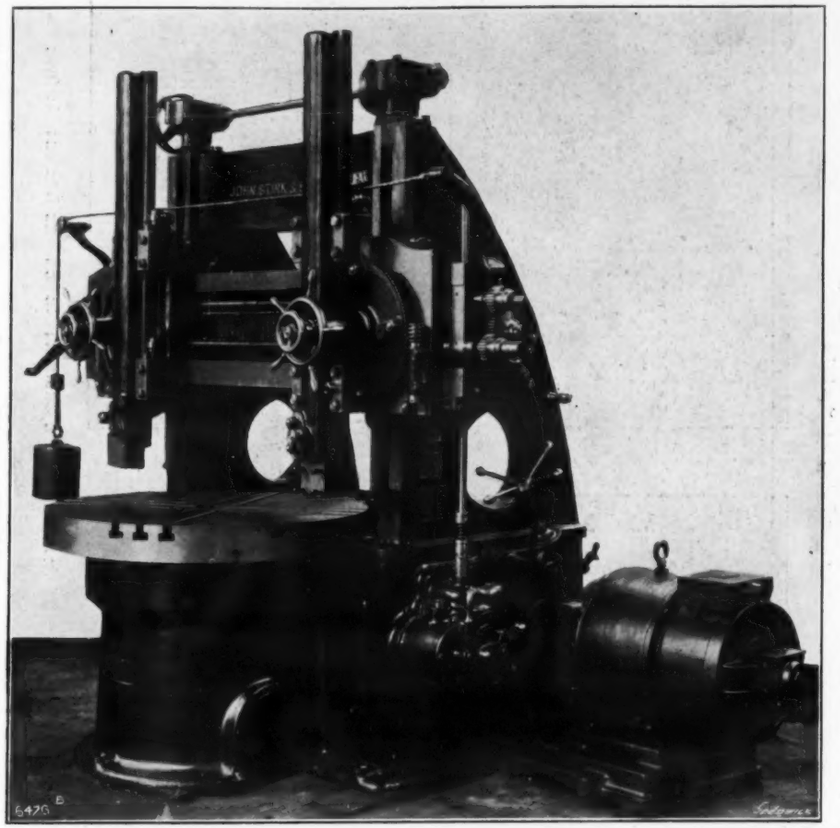
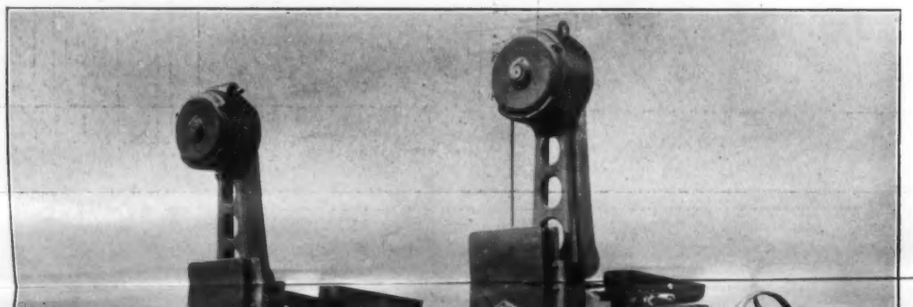


Fig. 22. 42-In. Boring Mill; Messrs. John Stirk and Sons, Ltd.



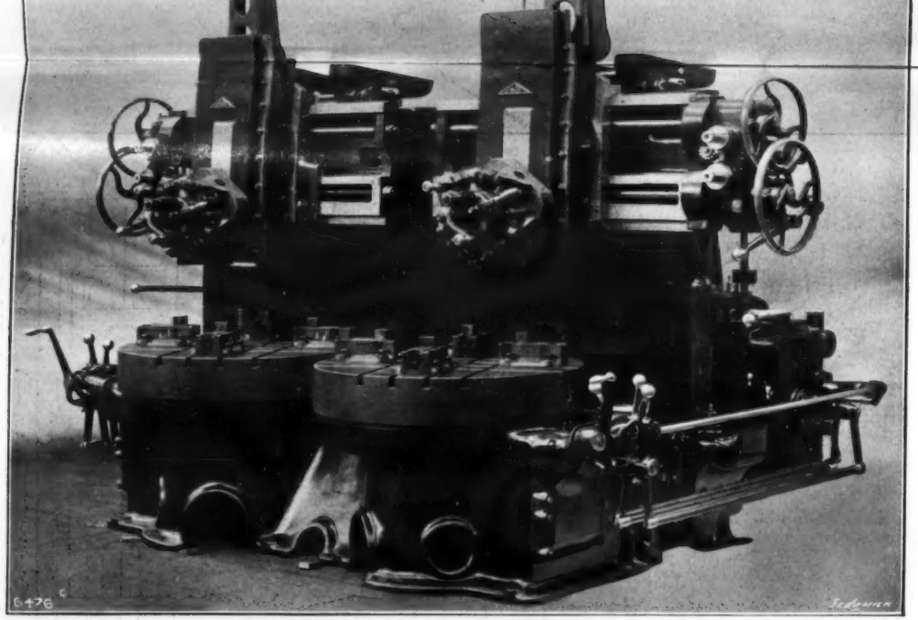


FIG. 23. 42-IN. DUPLEX BORING MILL; MESSRS. WEBSTER AND BENNETT, LTD.

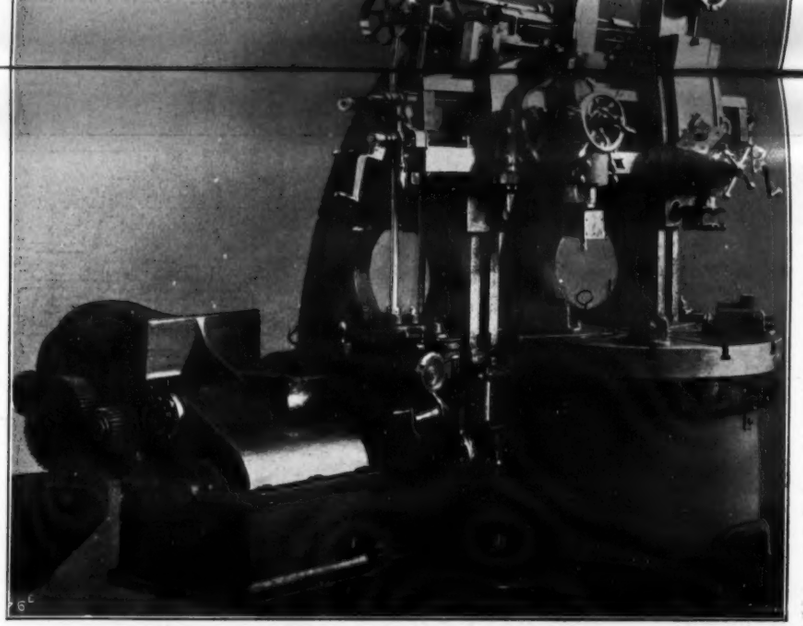


FIG. 24. 48-IN. BORING MILL; MESSRS. GEORGE RICHARDS AND CO., LTD.

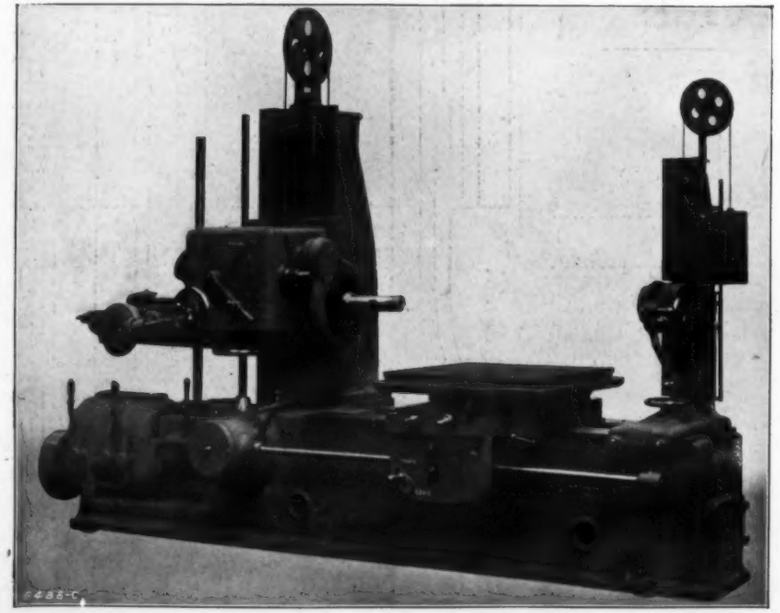


FIG. 25. 3-IN. HORIZONTAL BORING MACHINE; MESSRS. CUNLIFF AND CROOM, LTD.

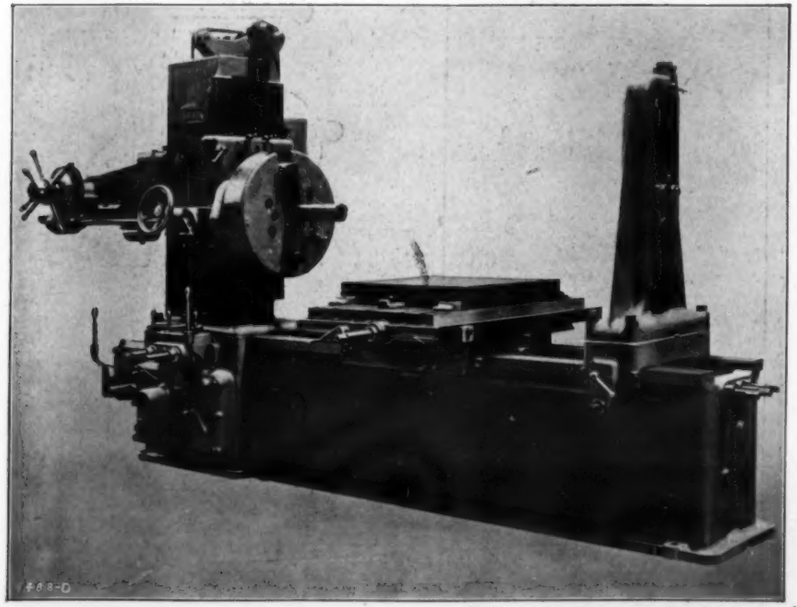
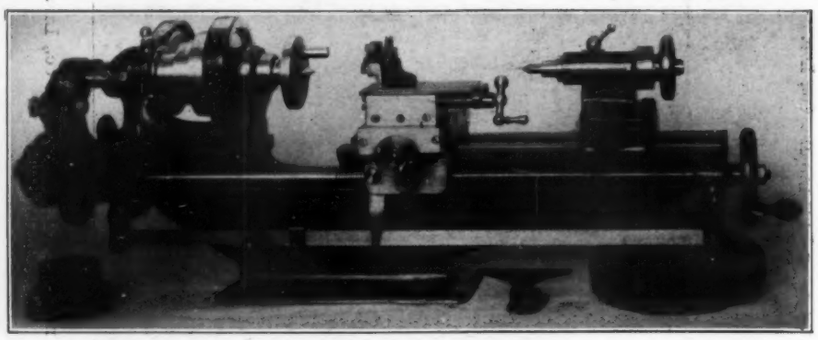


FIG. 26. 3½-IN., HORIZONTAL BORING MACHINE; THE DICKINSON MACHINE TOOL CO., LTD.

THE MACHINE TOOL AND ENGINEERING EXHIBITION AT OLYMPIA.

(*For Description, see Page* 301.)



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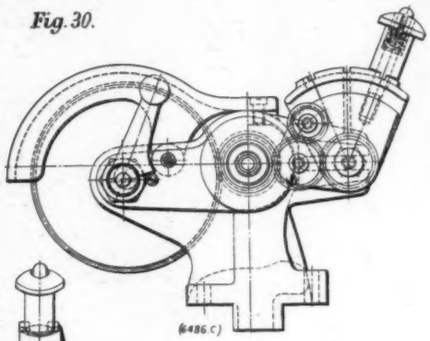

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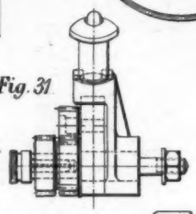

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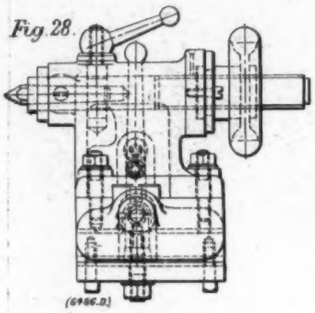

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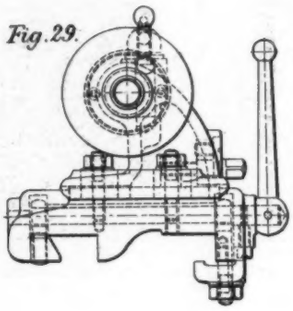

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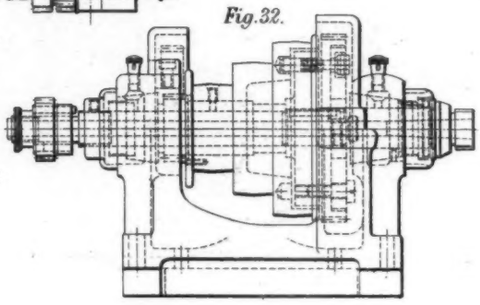

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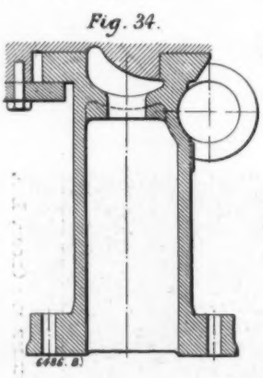

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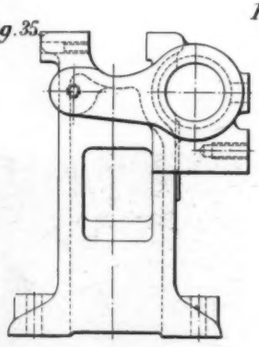

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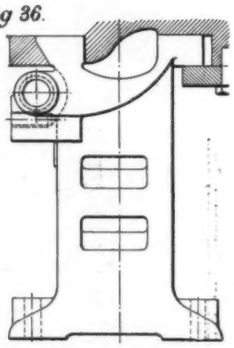

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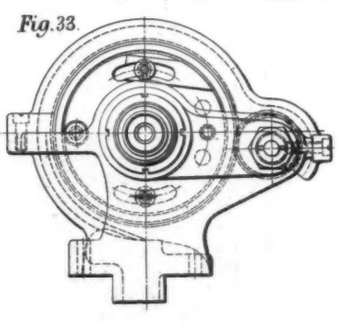

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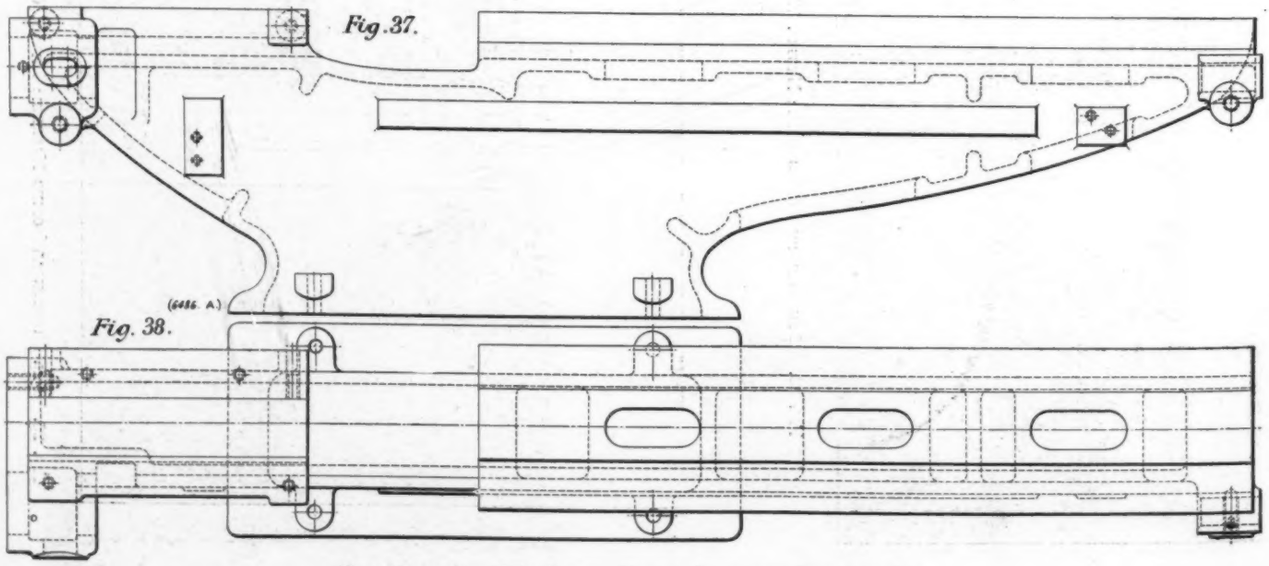

Fig. 37.

Fig. 38.

FIGS. 27 TO 38. 3½-IN. LATHE; MESSRS. DRUMMOND BROTHERS, LTD.

(*To face page* 305.)

THE MACHINE TOOL AND ENGINEERING EXHIBITION AT OLYMPIA.

(*For Description, see Page* 301.)

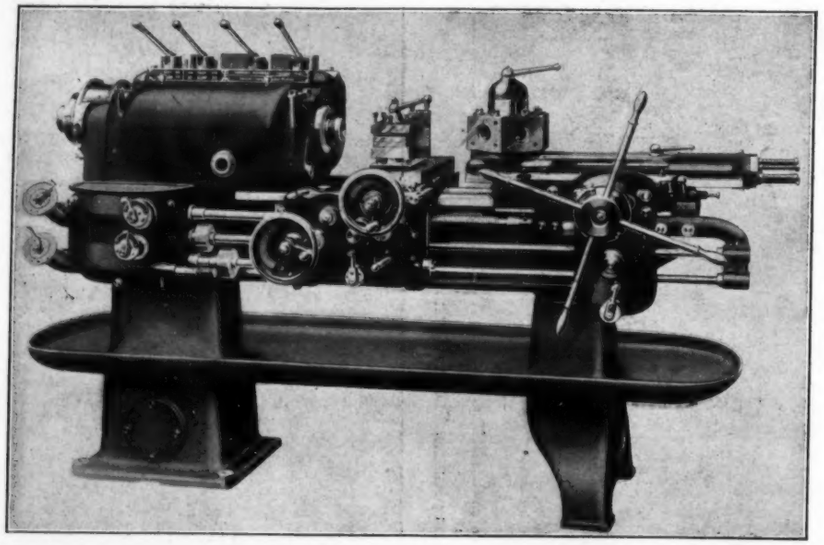

FIG. 43. 7-IN. CENTRE ALL GEARED CAPSTAN LATHE; MESSRS. H. W. WARD AND CO., LTD.

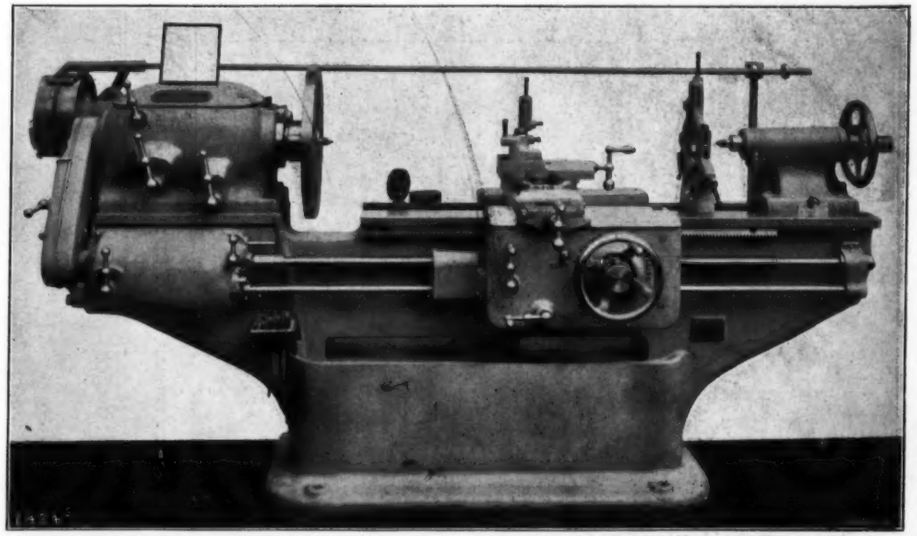

FIG. 45. 7½-IN. CENTRE SCREW CUTTING LATHE; MESSRS. THOMAS RYDER AND SONS, LTD.

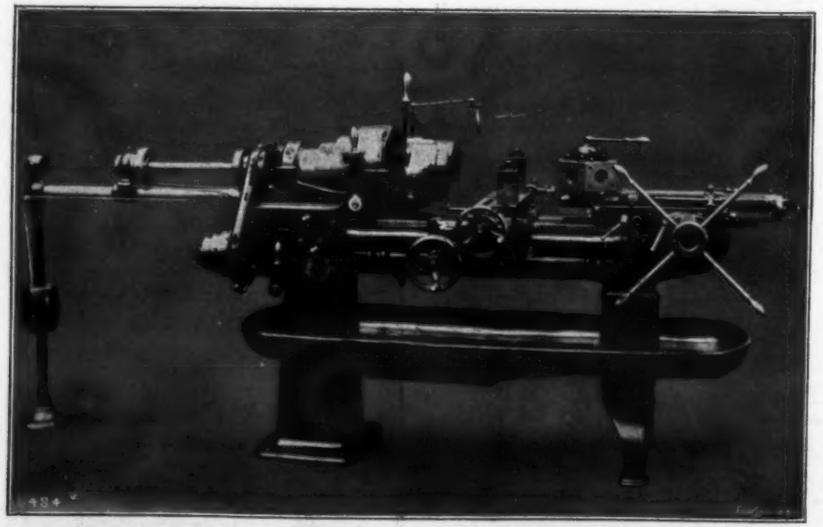

FIG. 44. 6½-IN. CENTRE FRICTION GEARED CAPSTAN LATHE; MESSRS. H. W. WARD AND CO., LTD.

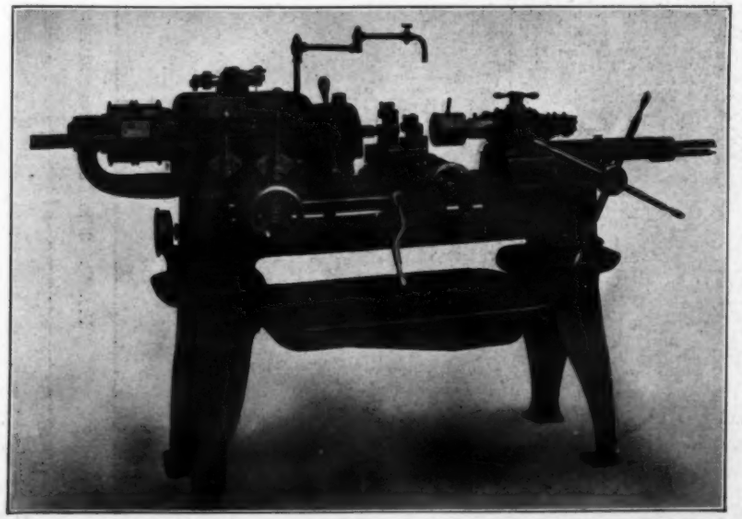

FIG. 46. 5½-IN. CENTRE CAPSTAN LATHE; MESSRS. POLLOCK AND MACNAB (1919), LTD.

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THE MACHINE TOOL AND ENGINEERING EXHIBITION AT OLYMPIA.

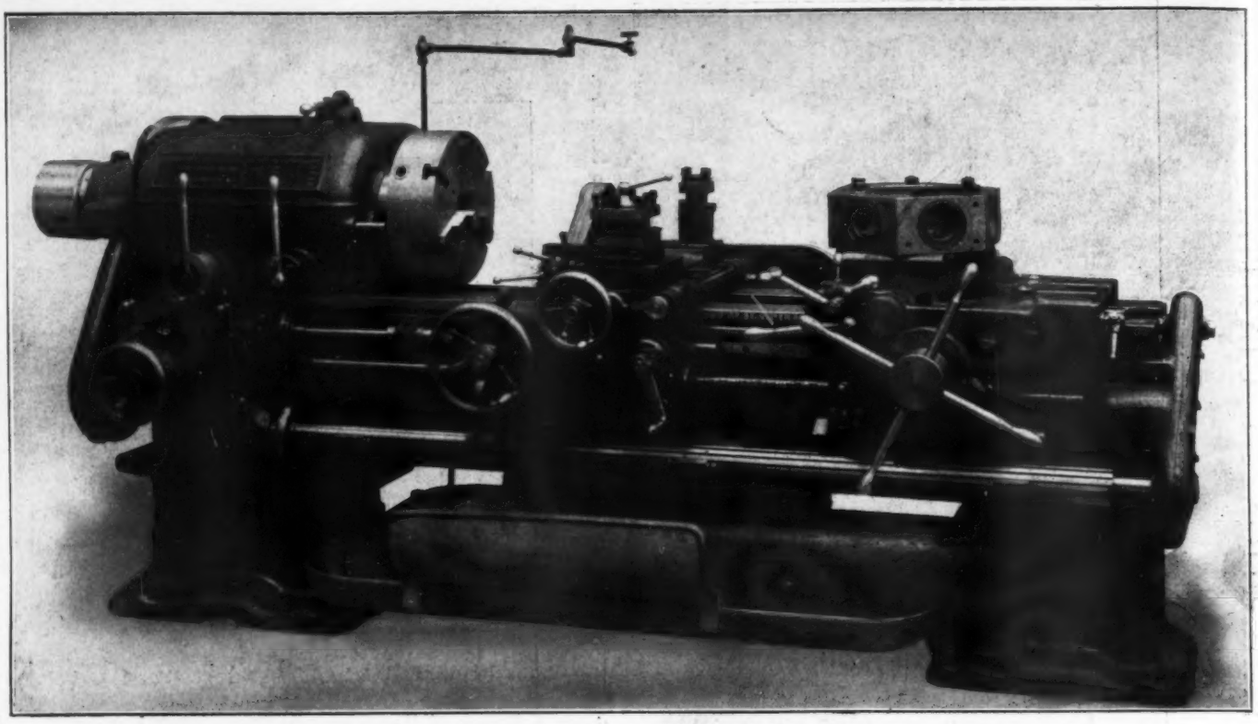

FIG. 47. 8-IN. CENTRE COMBINATION TURRET LATHE; MESSRS. POLLOCK AND MACNAB (1919), LTD.

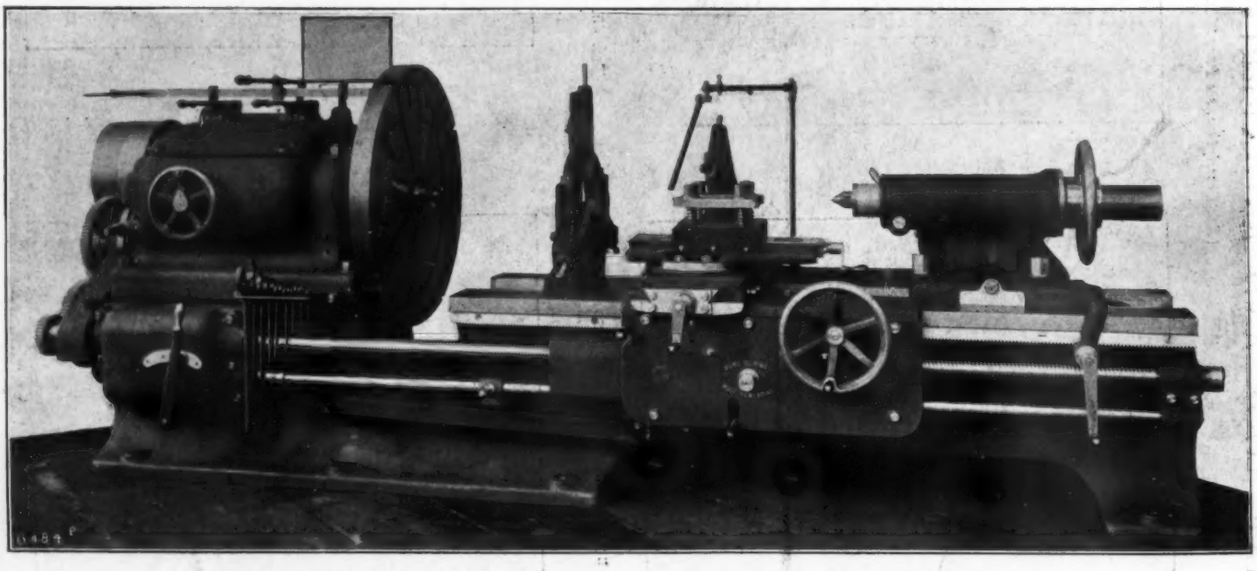

FIG. 48. 13-IN. CENTRE ALL GEARED GAP LATHE; MESSRS. THOMAS RYDER AND SON, LTD.

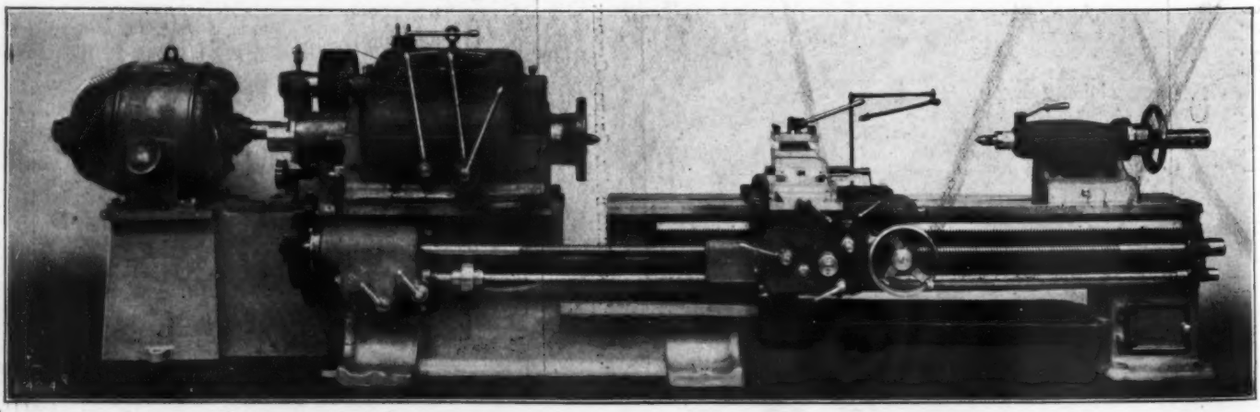

FIG. 49. 10-IN. CENTRE ALL GEARED GAP LATHE; MESSRS. GEORGE SWIFT AND SONS, LTD.

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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received on the Friday previous to the day of publication.

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.

TELEPHONE NUMBERS—3663 and 8578 GERRARD.

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With Six One-Page Plates and One Two-Page Plate of the MACHINE TOOL AND ENGINEERING EXHIBITION AT OLYMPIA.

NOTICE.

A few months ago the Proprietors of "ENGINEERING" were compelled to advance the price of this Journal to 1s. per copy, owing to the enormous increases in the cost of paper, engravings and printing, &c. Now higher transport and delivery charges involve a further increase to 1s. 2d. per copy, and this price dated from and included the issue of Friday, April 2, 1920. As the postal rates have been again increased, the price of single copies sent by inland post is now 1s. 2½d.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions still imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

ENGINEERING.

FRIDAY, SEPTEMBER 3, 1920.

THE DEVELOPMENT OF AMERICAN SHIPPING.

AT the present time, when British shipping is still only in process of recovering from the losses sustained during the war, the efforts of the United States legislature to foster the development of American shipping may well have the attention of those interested in British shipping and British industry. The most recent expression of that policy is to be found in the Merchant Marine Act, 1920, which is popularly known as the Jones Act, from the name of the father of the Bill, Senator Jones.

This Act, which was formally approved by the President as recently as June 5, 1920, commences with a declaration that it is the policy of the United States to do whatever may be necessary to develop and encourage the maintenance of a merchant marine of its own, of the best equipped and most suitable types of vessels, sufficient to carry the greater portion of its commerce and serve as a naval or military auxiliary in time of war or national emergency, and it enjoins the United States Shipping Board always to keep this in view as the primary end to be attained. The Board was constituted under an earlier Statute, the Shipping Act of 1916, primarily for the purpose of creating a fleet of auxiliary vessels for use in the war, but its constitution and duties are greatly expanded by the new Act. The number of commissioners on the Board is raised from five to seven, and, incidentally, the salary of each commissioner is increased from 7,500 dols. per annum to 12,000 dols. Two commissioners are to be appointed from the States bordering on the Atlantic, two from those on the Pacific, one from those on the Gulf of Mexico, one from those touching the Great Lakes, and one from the interior.

In 1917 the Board took over the German ships in the United States harbours, and by Section 4 of the new Act all vessels acquired by the President under certain war legislation are transferred to the Board, except vessels in the military and naval service. It may therefore be assumed that the Board are already owners of a large fleet of merchant vessels. It is not, however, within the general intention of the statute that they should act permanently as shipowners, so they are directed to sell their vessels as soon as may be practicable and consistent with good business methods.

The sales ordered by the Act are, it is important to note, to be made to persons who are citizens of the United States; and in order to facilitate such transactions, the payment of the purchase price and interest may be deferred for a period not exceeding fifteen years. Sales may be made to aliens only of such vessels as the Board deem unnecessary to the promotion and maintenance of an efficient American merchant marine, and only where the Board have failed, after diligent effort, to sell the vessels to citizens of the United States. In these cases payment of the price is not to be deferred beyond ten years. (Sections 5 and 6.)

The Board are also directed to investigate and determine, both now and from time to time in future, what steamship lines should be established from ports in the United States or their possessions for the promotion and development of the foreign and coastwise trade of the United States and an adequate postal service, and to determine the size, type, speed, &c., of the vessels required and the frequency of their sailings. The Board may sell or charter vessels to citizens of the United States who agree to establish such lines, on such terms as may be considered just and necessary to secure the desired service, and may even operate vessels on such lines themselves until privately-owned services can be established or unless it appears that the lines cannot be made self-supporting or that the maintenance of the service is unbusinesslike and against the public interests (Section 7).

The Board, it is laid down in the act, are also to investigate the causes of congestion of commerce at ports and the appropriate remedies, as well as the subject of water terminals, piers, docks, warehouses, &c., with a view to suggesting the most appropriate types for the different localities. They have also certain powers of making representations to the Inter-State Commerce Commission where they consider that the rates or regulations of common carriers by rail are detrimental to the development of transport facilities in connection with water-borne commerce (Section 8).

In connection with the building of new ships there is an important enactment in Section 11 to the effect that during the period of five years from the commencement of the Act the Board may set aside annually out of the receipts from its sales and operations, a sum not exceeding 25,000,000 dols. as a "construction loan fund," to be used in aid of the construction, in private shipyards in the United States, of vessels for the steamship lines deemed desirable and necessary by the Board. It is enacted in almost anxious terms that the vessels are to be of the best and most efficient type and are to be equipped with "the most modern, the most efficient and the most economical machinery and commercial appliances."

No aid is to be for a greater sum than two-thirds of the cost of the vessel, and the Board is to have security for repayment and for the maintenance of the service for which the vessel is built. The Shipping Act of 1916 contained a significant direction to the Board to investigate the relative cost of building vessels in the United States and in foreign countries, and the relative cost, advantages and disadvantages of operating vessels in foreign trade under United States and foreign registry.

The two Acts of 1916 and 1920 contain also many interesting provisions relating to common carriers by water, including a prohibition of unfair competition in order to drive a carrier out of the trade, of retaliation against shippers by the refusal of available space accommodation, and of contracts which discriminate unfairly between shippers.

The new Act provides also for the establishment by the Board of steamship lines to the "island territories of the United States"—i.e., the Philippines and Hawaii—for passenger and commercial traffic, until the services can be taken over and operated by private enterprise. It is interesting, in these days when a noisy minority in this country is crying so loudly for nationalisation of the mines and railways, to observe how steadily the policy of this United States Statute is directed towards the encouragement and development of private shipbuilding and shipowning. Owners of United States vessels engaged in foreign trade are even to be given certain exemptions from war and excess profits taxation as regards profits invested in the building of new vessels in the United States; and all mails of the United States—so far as carried by ship—are to be carried, if practicable, on American-built vessels documented under the laws of the United States. The Act contains also various provisions as to the sale and mortgage of American vessels and other matters, which are perhaps of less general interest to this country.

The duties of the United States Shipping Board correspond to some extent to those of our Board of Trade, and of our Ministry of Transport in its own domain of land transport; but British shipbuilders and shipowners cannot afford to ignore the challenge

latent in the provisions of the new Act, because it carries with it cause for some apprehension, and certainly reason for establishing our shipping industry on a sounder economic basis than it at present possesses.

TRADE PROSPECTS IN AUSTRALIA.

In 1908 the Board of Trade appointed special Commissioners to report on the commercial and industrial conditions in each of the Overseas Dominions. The reports issued, several of which we have already reviewed, have been of the greatest interest and importance, which is enhanced by the circumstance that the Commissioners are permitted to express their own views and record facts as they see them, and not necessarily merely such views and facts as commend themselves to the political head for the time being of the Board of Trade.

The report on conditions in Australia just issued shows that there has during the past six years been a large proportionate reduction in the imports from the United Kingdom. In 1913 our share was 51·82 per cent., which fell in 1918–19 to 36·42 per cent. This decrease was no doubt an inevitable consequence of the war, the principal gainers being America and Japan. During the period in question imports from the United States rose from 13·68 per cent. up to 28·63 per cent. of the total, and those from Japan from 1·19 per cent. up to 8·64 per cent. Whether these gains at our expense are to be permanent or merely temporary is a matter of much importance. On the whole our prospects would appear to be good. The enormous rise on the American exchange is seriously handicapping exports from the United States. The report suggests that future American competition will be felt mainly in machinery, hardware, metals, motor-cars and small tools. In some classes of small tools, however, of which America has had almost a monopoly in the past, it seems to us that there is a good prospect for British trade. Owing to the exigencies of the war we had to make gauges and accurate screws on an unprecedented scale and devised many new and improved methods of manufacture. It will be disheartening if with this special experience we cannot supply not merely home requirements for such commodities but also secure a large share in the foreign demand. As regards the Japanese, some of their goods are stated to be of excellent quality, but it would appear that this is the exception rather than the rule and, as a consequence, Japan may well fail to maintain the position she secured in the Australian market during the war years.

As for the British manufacturer, the report suggests that Australians, with less excuse than those who are not of the family, have been inclined to take at its face value our British habit of self-depreciation and to believe that we are intensely conservative and lacking in enterprise. It certainly is true that, without the assured home market enjoyed by most of our competitors, there is less inducement here than elsewhere to devote large sums to the development of certain fields of industrial effort. Nevertheless, where it is possible by patents to secure protection at home, we have not been lacking in enterprise. The nation which has been responsible for such revolutionary changes in the arts as are exemplified by the steam turbine and the pneumatic tyre cannot fairly be accused of ultra-conservatism. The report states that British goods are, on the whole, held to represent the best value for the price paid, and lays special emphasis on the importance of maintaining our prestige in this regard.

A danger noted in the report is the too frequent appointment of ill-equipped and unsuitable representatives. Whether this be due to the nepotism of directors or to the reluctance to pay what a first-class man may require for his services, the result is equally unfortunate. Another error to be shunned is the despatch of jeremiads in regard either to conditions at home or the Commonwealth.

A noteworthy point in the recent industrial history of Australia is the fact that the Government has encouraged, and indeed in many cases insisted on, trades and industries being formed into combinations, which in some respects recall the Kartels which were so successful in developing the trade of Germany. Thus the Commonwealth Government has made arrangements by which no minerals or metals except gold, silver or platinum may be exported save through the Australian metal exchange. Further, a zinc producers' association has been formed which controls the whole of the Australian output, and corresponding associations have been formed in connection with the copper and the gold industries. The ultimate and perfectly legitimate aim of the Commonwealth is to have all metallic ores reduced in the Colony, so that refined metal only shall be exported. To this end Australia is apparently prepared to make substantial sacrifices for a time, just as the United States did in their determination to secure a rapid development of the American steel and iron trades. This determination, it may be noted incidentally, had not a little to do with the defeat of the scheme for securing a Hun domination of the world, since for a short but highly critical period 70 per cent. of the shell bodies we used on the Western front came from the United States.

Having in view the development of its own industries the Commonwealth has actively encouraged the formation of a number of combines, amongst which may be noted the Broken Hill Smelters' Proprietary, which now produces 160,000 tons of lead per annum. As originally constituted this association dealt with the concentrates of certain companies only, but under Government pressure its scope was extended and under the style of the Associated Smelters' Proprietary it now controls and treats the whole of the Broken Hill output, with the exception of that of the Sulphide Corporation. Similarly another combine has been formed to work up the copper mined in the Commonwealth into strips, bars, rods and wire.

Again, an agricultural combine has been formed which aims at the control of the whole Australian pastoral and agricultural production, which it is hoped to market without the use of intermediaries, whilst all purchases from overseas are similarly to be made through the organisation instead of by the farmers individually.

Australia is a country in which nationalisation has been carried further than anywhere else. Private enterprise in opening up and developing the country by irrigation and railway construction has been actively discouraged, and it can hardly be doubted but that the rate of settlement has been slackened materially thereby. An engineer has in the nature of things less initiative in public than in private employ. Moreover, the weeding out of the inefficient is less drastic, and it not infrequently happens that a State engineer is overloaded with unnecessary clerical work. At the same time it is quite possible that in new countries some temporary advantage may attend the policy in question since capital is not only scarce but is commonly less considerate of the public weal than in more settled areas. The ultimate outcome will probably, however, be the same as it has in Europe, where State management and inefficient management have commonly been synonymous terms. It is, of course, true that under an autocratic *régime* in Germany, the State railways were not badly conducted, but we believe they are not to be credited with originating a single important improvement in transportation or in its safe conduct. Similarly it has been the American telephone system, and not the State services of Europe, which have led the way in all important developments in telephony. It is probable, therefore, that history will repeat itself in Australia. Possibly the recent railway returns are an indication that this stage has now been reached with this, which is one of the oldest established public services in the Commonwealth. All the lines now show very large deficits, but of course these may be due to temporary causes resultant on the war. Nevertheless the report notes that little has as yet been done in the matter of handling grain in bulk, in accordance with the methods so efficiently worked out on the American lines.

The shipping venture, on the other hand, has so far proved a most successful speculation, but of course the conditions have been wholly abnormal. Freights have been such that the whole capital cost has been repaid in a couple of years and the ships constituting the fleet are now worth more than was paid for them. The present policy is to charge the same rates as do the conference lines, but without the rebate system maintained by these, a system which should perhaps be rendered illegal by law as opposed to public policy. In regard to private shipping, a recent act makes compulsory great improvements in the accommodation provided for the crews of vessels engaged in the coastwise trade. A similar reform is badly needed in the Transatlantic services, where the naval officers who commanded some of the converted liners during the war were appalled at the accommodation provided for crews and firemen.

An important State enterprise is proposed in Victoria, where the Electricity Commission has recommended the erection of a super power station at Morwell, which is the centre of almost limitless deposits of brown coal. The plant is at the outset to be of 50,000-kw. capacity, and the selling price of the current at Melbourne is estimated at 0·434*d.* per unit, a figure which may be compared with the ½*d.* per unit charged in pre-war times in the North-East Coast area. The only other important electrical developments foreshadowed are in Tasmania, the one State of the Commonwealth where there is much scope for hydro-electric installations. Existing hydro-electric stations in Tasmania develop 18,000 h.p. This is to be increased to 57,000 h.p. during 1921, and to 70,000 h.p. in about two years' time. The current will be used mainly in electro-metallurgic operations.

Queensland has gone further than any of her sister States in nationalising industry. There are, in fact, State butcher shops and State fish shops, and a State cannery, but all these have been too short a period in service to provide any reliable indication of their ultimate efficiency. As matters stand the State cannery has been doing well, but this is attributed to the abnormally high prices and great demand for tinned pineapple. The State trawler, on the other hand, is said so far to have proved but an expensive experiment. State cold storage works are in construction and State steel works have been decided on. It would be interesting to know whether there is any connection between these activities and the abnormally high taxation of the Province. The taxation in 1918–19 was 79*s.* 10*d.* per head as compared with 53*s.* 3*d.* in the most highly taxed sister States. Moreover, under a new Act the amount raised by taxation in Queensland is to be increased to 5*l.* 9*s.* 10*d.* per head. It would seem from the report that, as in this country, the workmen, though making abnormally high earnings, are for the most part spending them in various forms of self-indulgence, whilst the middle and higher classes have reduced their expenditure and are investing what they thus save in war loan or depositing it in the savings banks.

Under private direction two steel works have been established, both in N.S.W. Of these that at Lithgow, established in 1905, produced 19,687 tons of steel ingots in 1917. The Newcastle works, established in 1915, produced 185,512 tons of steel ingots in 1917. This company is stated to have an enormous reserve of ore at Iron Knob, worked in open quarry.

Labour troubles throughout the Commonwealth have been pretty serious, and the report states that many Australian thinkers believe that there is an urgent need for an educational campaign, in part to impress on employers their individual and national responsibilities, and on the other hand to dispel the present ignorance of the workmen regarding the true facts governing production; and to make them realise the necessity for self-discipline, and that successful manufacturing industry is in the ultimate dependent on mind rather than on capital or labour.

ELECTRIC POWER SUPPLY IN GLASGOW.

Whatever may be said for, or against, municipal trading there is no doubt but that in the business of electric supply many very admirable and successful municipal systems are to be found. This applies particularly to the larger of the provincial towns. To a considerable extent this may be explained by the technical nature of the business concerned. It is now fairly well understood not

only by engineers, but by the general public, that electric supply can be most efficiently carried on when the area of supply is large, since this in general leads to a better load factor. It has taken very many years for this fact to be appreciated, but recent electrical legislation and its reception by the public shows that the root idea of the matter has at length been grasped. Initial ideas which confined supply systems to municipal areas, while unsound generally, had advantages from the point of view of large towns. They from the first were given supply areas which were reasonably adequate from a technical point of view and which enabled sound supply systems to be built up. Many of the large provincial towns have taken full advantage of this favourable position in which they were placed and electricity systems have been established which will stand comparison with the best of the company operated schemes.

Among these towns Glasgow takes a high place and from 1892 when the corporation acquired the electric light installation from Messrs. Muir, Mavor and Coulson, the story has been one of continual advance. Incidentally it is curious to note that Glasgow is one of the towns which still runs its power and lighting system independent from the tramway system, the latter having its own generating stations. Reference to this fact calls to mind the, at one time, acute but now somewhat amusing controversy which years ago raged round proposals to supply electric tramways from lighting stations. It is a curious electric lighting station which now-a-days would not be glad to get a tramway load. We do not at the moment recollect the local considerations which have determined the retention of the divided system in Glasgow, but in any case the power and lighting stations have certainly made very satisfactory progress without the traction load. Very full advantage has been taken of the general power supply possibilities and the system is now one of the largest in the country.

The original Glasgow stations were in Miller-street and John-street and were erected in 1890. In spite of difficulties which were common in the early days of most undertakings a further station, which superseded the others, was erected in Waterloo-street in 1893. This station was placed near the centre of the load which was certainly the correct position in view of the technical experience of that day. As the load grew, however, the usual difficulties with fuel supply and ash disposal were encountered, and in the period 1900 to 1904 the Port Dundas and St. Andrew's Cross stations were erected. These stations were better placed and with turbo-alternator plant added in later years have been enabled to carry the very large load which has grown up. A few years before the war, however, it became evident that the future possible and probable load of the city could not be dealt with at these stations. This was particularly the case in connection with the water available for condensing purposes, and accordingly in 1912 on the advise of Mr. W. W. Lackie, then the engineer to the electricity department, an area of 13½ acres was purchased on the banks of the Clyde for a future station. The erection of a station on the site was proceeded with and although delayed during the war the first half of the station has now been completed and was formally inaugurated on Wednesday last.

The Dalmarnock power station as the new station is called, is in the Dalmarnock-road and standing as it does on the banks of the Clyde is very adequately placed from the point of view of condensing water. The importance of this water supply aspect of the power generation problem is one which only the great growth in power demands of recent years has caused to be generally realised. The Dalmarnock station is planned on generous lines and will have an ultimate capacity of 200,000 k.w. It should enable the Glasgow load to be dealt with for many years to come and should at the same time enable all modern economies in technical procedure to be practiced. It has been planned to contain a uniform generating unit of 24,000 h.p. throughout. Five of these units are contained in the first half of the station which is now completed. In addition there are two 400 K.V.A. geared turbo sets for supplying power to auxiliary machinery.

The station is not only alongside the river Clyde but also directly alongside the Caledonian Railway, so that all conditions are favourable for economical operation. Coal comes by rail and the wagons are tipped by an electrically-operated ram. It is then carried by a conveyor to a distributing centre from which other conveyors take it either to the boiler house silos or the coal store. The boiler house is a three-storey building, the ground floor being occupied by the forced draught fans and motors and the ash removed hoppers. The first floor is occupied by the boilers and the top floor by the induced draught plant, economisers, coal silos and hot wells. Each boiler room contains eight Babcock and Wilcox marine type boilers each with a maximum output of 62,000 lbs. of steam an hour. The final steam conditions are 275 lbs. pressure and 700 deg. F. total temperature. Three boilers are sufficient to supply steam to one turbine and the coal silos are of sufficient capacity to maintain the supply for 20 hours in the event of stoppage of the conveyors.

The site on which the station stands was found quite suitable to carry heavy buildings, but for greater security a concrete raft, 5 ft. thick has been laid over the whole area of the boiler house, turbine room, and switch house. The buildings are of reinforced concrete. The original designs were for steel buildings but a change had to be determined on during the war on account of steel shortage. The alternators generate at 6,500 volts which is stepped-up to 20,000 volts for distribution to substations. A interesting feature of the station is that the whole of the high-tension switchgear is of the enclosed non-clad type supplied by Messrs. Reyrolle, of Hebburn-on-Tyne. Iron clad totally enclosed gear of this type has made much progress of recent years, but we think this is the first large station to be completely equipped in this way. With hope to deal with this as well as other interesting features of the station in more detail later. The station was designed by Mr. W. W. Lackie, but since his appointment as an electricity commissioner its completion and operation have fallen to Mr. R. B. Mitchell, the new engineer and manager of the electricity department. As Mr. Mitchell was previously assistant engineer to Mr. Lackie he has naturally been concerned with the station from the first.

THE BRITISH ASSOCIATION.

SECTION G.—ENGINEERING.

(*Continued from page 287.*)

FARM TRACTORS.

WHEN the meeting was resumed on Wednesday, August 25th, Professor Jenkin called upon Colonel R. E. Crompton to take the chair, as the first paper on the programme, viz., that by Mr. S. F. Edge, on "Farm Tractors Regarded from the Point of View of the User and Potential User" dealt with a subject with which Colonel Crompton was more familiar than he (Professor Jenkin) was himself. After occupying the chair, Colonel Crompton called upon Mr. Edge to read his paper.

The author having had some twenty years practical experience with agricultural tractors from the original Ivel tractor, up to the latest machines built, is, well qualified to deal with the subject. He considers the comparatively slow progress made with agricultural tractors to be mainly due to the fact that the earlier forms were not sufficiently powerful, so that tractors giving good results on light land failed to meet requirements when used on clay or other heavy soils. If these earlier machines had been used only for cultivating, grass cutting, drawing reapers and binders, &c., the author considered that they would rapidly have become popular. There was, also, he said, less incentive to use tractors in the early days when horses and labour were much less costly than at present, and also when the price of corn was so low that the farmer had little inducement to plough any but his best land for growing it.

With the different conditions now existing the farmer, by employing tractors, could plough his heavy land in the summer and thus grow corn at a better profit than would be possible with horse ploughing. For his own work on heavy weald clay, and with fields ranging from 5 acres upwards, the author considered that a tractor capable of drawing a three-furrow plough is desirable and effected a notable saving in labour. At the present time, he stated that tractors fitted with two-cylinder, horizontal, slow-running engines are more generally satisfactory than those with high-speed four-cylinder engines, although in the future he expected to see tractors with six-cylinder engines largely employed. The cost of a tractor constructed throughout of really first-class materials was, however, likely to restrict sales, but he thought the increased first cost would be more than justified by the greater reliability and durability obtained. In this connection it must be borne in mind, the author remarked, that tractors were usually in the charge of persons unskilled in mechanical matters, who were quite unable to ascertain the causes of troubles or to remedy them when they occurred. It was therefore necessary for the manufacturer to eliminate the liability to breakdown in every possible way. With regard to the different types of tractors he considered the self-contained motor plough extremely useful if sufficient ploughing existed to justify the purchase of a machine for this work only, although, for ploughing and deep cultivation, he preferred a rather heavy two-cylindered tractor. For reaping, mowing and hay-making somewhat faster machines were better and were capable of rapidly getting through an immense amount of work. For road-haulage work the fitting of rubber blocks between the strakes of the wheels was useful, but, in the future, he thought the tendency would be to employ different machines for road and field work. The "caterpillar" type of tractor, the author considered, would continue to decline in popularity owing to the cost of maintaining the chain tracks. During the course of the war a large number of American tractors had been imported into this country which were quite unsuitable for the work they had to do, and which would tend to hamper the development of the British tractor industry, but the author thought that, if British manufacturers aimed at efficiency, they would eventually obtain a ready market for the products as the tractor was the key to really profitable farming in the British Isles.

In thanking the author at the conclusion of the reading of his paper, Colonel Crompton mentioned that in his address to the Junior Institution of Engineers two years ago, on the subject of work for engineers of the future, he had called attention to the importance of food production. He then briefly traced the development of the application of power to agriculture from the Leeds Agricultural Show of 1861, at which Messrs. Aveling of Rochester had exhibited what was, in effect, a portable engine made to drive its own wheels so as to be self-propelling. Mr. Edge, who had just given his experiences in the matter of food growing, had referred to the necessity for rendering agricultural machinery fool-proof, and this, Colonel Crompton stated, was an even more important consideration if the machinery were to be used in the South of England than if it were to be employed in the North, where the inhabitants generally understood mechanical appliances better. When mechanical transport appliances were used on the land, Colonel Crompton continued, special difficulties were introduced by the access of mud and dust to the working parts which caused excessive wear, while if the parts were covered in they were difficult to get at. On the question of wheels *versus* chain tracks he disagreed somewhat from the author in his condemnation of the latter, and stated that, for some classes of work, chain tracks were essential. Some American caterpillar tractors were more or less foolproof and had given excellent results in the hands of intelligent men; they were particularly useful for cross-ploughing and cross-harrowing owing to the fact that they compressed the soil less than wheeled tractors. The great advantage of mechanical power in agriculture was that much better aeration of the soil was obtained than was possible with animal traction. Irrigation schemes in tropical countries would undoubtedly fail unless the soil were properly aerated to a sufficient depth, for which depth mechanical haulage was essential. The difficulty in connection with the development of internal-combustion engines was, however, the shortage of

liquid fuel for them. Oil was now being used for firing the boilers of ocean-going steamers, which Colonel Crompton thought was undesirable since this could be done with coal, while liquid fuel was essential for some services and should be reserved for them. Coal, he considered, should be employed as fuel wherever possible. Even for agricultural traction steam-driven vessels of the Clarkson type, in which coke was used as fuel, might be employed.

Professor Jenkin, who spoke next, said he thought a few matters in connection with tractors were capable of improvement. He suggested that a really good book of instructions should be sent out with each tractor and also that makers should so design their machines that they could be left out in any weather without harm. He also thought the removal of the spuds from the driving wheels when a machine was required to run on the road should be made a quicker and easier operation, and further suggested that the ploughs themselves were capable of considerable improvement. Ploughing usually consisted of drawing a comparatively blunt body through the soil, but the operation, he thought, could be accomplished more scientifically by using cutting edges of the rotating type which were now available. Less power would be required and better results obtained by the latter method. Bluntness of a plough increased the power required to draw it enormously, and he therefore thought it would be an improvement to employ high-speed steel for the cutting edges which would then keep sharp.

Mr. E. Pickworth Farrow, M.A., D.Sc., the next speaker, called attention to the importance of accessibility, pointing out that some jobs which were extremely simple in the maker's shops were very difficult to carry out by the user. Manufacturers, he said, would do well to watch their products in use on a farm, and they might then be surprised at the type of man responsible for handling tractors. These complicated machines were frequently in charge of ploughmen who had no experience of machinery of any kind, and who found it too much trouble even to oil the wheels of a horse-drawn plough. Lubrication, which was regarded as important for motor cars, was, the speaker stated, of even greater importance for tractors, and makers should concentrate attention on this matter. On the whole, the speaker preferred a light tractor with a high-speed engine, but he was of the opinion that horses would never be quite superseded for farm work.

Wing-Commander T. R. Cave-Brown-Cave, who followed, supported Professor Jenkin in his suggestion as to the supply of good instruction books, and also thought that tractor makers might institute a system of visiting inspectors. Such men could teach users much, but they would also learn a great deal themselves regarding the conditions under which the tractors worked. This information would, he thought, be of the utmost value to designers.

The only other speaker on this paper was Professor Hudson Beare, who referred to the matter of rendering tractors foolproof, but pointed out that, when machinery was put into the hands of totally uninstructed persons, it was not surprising that the results were unsatisfactory. Agricultural colleges, existed however, and he considered that a course in agricultural engineering should be compulsory at such institutions. The course could include instruction in the use of tractors, and, if this were done, he thought the number of breakdowns would be greatly reduced.

Mr. Edge then replied to the discussion, but as the time allotted to the paper had almost elapsed his remarks had necessarily to be somewhat curtailed. In reply to the chairman's remarks on chain-track tractors Mr. Edge said he quite admitted that these would be useful for certain purposes, but he thought they would be in the minority. The main point about the use of tractors was to remember that the tractor was not required to do the same work as a horse. The system of cultivation had to be altered to suit the former, which worked best in hot, dry weather, whereas a horse could do more work in cool, damp weather. With regard to the value of soil aeration he mentioned an instance from his own experience in which by ploughing 12 in. deep the yield of oats from a certain field had been increased in the ratio of 25:3. He disagreed from the chairman with regard to the use of liquid fuel for marine propulsion, expressing the view that if a sufficient number of concerns committed themselves to the use of this fuel, the shortage difficulties would be overcome. The matter of instruction books, which had been referred to by some of the speakers, was important, and such books were, in fact, issued by most makers, though not by all. The difficulty was that users did not work by the books. He agreed with Professor Jenkin that the ordinary plough was a somewhat primitive appliance, but several improvements were being developed. The double disc plough, for instance, when used for ploughing 12 in. deep, required only half the power necessary to draw a plough of the ordinary type. Another machine, of Swiss origin, employing rotating mechanical cutters was particularly promising. It must be admitted that the usual method of bursting up the earth was crude, and that the difficulties increased rapidly as the speed of ploughing was augmented by the use of tractors. Accessibility was certainly a most important item from the user's point of view, and one which was not always sufficiently considered by the makers. In one of his, the speaker's, own tractors, he had had the misfortune to break one of the differential pinions, and, to replace this pinion, it was found necessary to dismantle the machine completely, even to the extent of removing the engine. The system of visiting inspectors suggested by Commander Cave-Brown-Cave, he thought an excellent one, as also was Professor Hudson Beare's suggestion regarding the training of tractor users at agricultural colleges. It was possible to train a man in the use of a tractor in a very few weeks, provided he had a slight mechanical instinct.

High-Speed Petrol Engines.

At the conclusion of Mr. Edge's reply, Professor Jenkin resumed the chair, and called upon Mr. H. R. Ricardo to read his paper on "High-Speed Petrol Engines," which we commence to reprint on page 325 of this issue. The reading of the paper, however, occupied a considerable time, so that Professor Jenkin, on its conclusion, suggested that the discussion should be left over until the following morning, so that members might have an opportunity of studying its contents in the meantime. This was agreed to, and, after a vote of thanks to Mr. Ricardo had been passed, the chairman explained that the paper by Professor W. H. Watkinson, on "Methods of Obtaining Ignition in Internal-Combustion Engines with Low-Compression Pressures" had been withdrawn, but that Professor Watkinson would read a paper which had been announced on the programme for the following day.

A Dynamical Method of Raising Gases to High Temperatures.

The paper bearing the above title was then read by the author, and as we reprinted it in full on page 276 of our last issue we may at once proceed to deal with the discussion. The chairman, Professor Jenkin, said the paper left him somewhat bewildered, and he inquired what was the object of the suggestion made and asked how it was to be applied in practice; or had it been brought forward to explain failures which had occurred? To this the author, at once, replied that his object had been to draw attention to possibilities and to set inventors to work devising applications. He had called attention to a conceivable method by which higher temperatures could be obtained than by any other method, and this could be done without employing excessive pressures. He left the development of the idea to others. After this explanation, Professor Jenkin invited the members present to discuss the paper, and the first speaker, Professor W. Cramp, said he thought the suggestion made might be applied to many industrial processes. He asked the author for information as to the temperatures actually attainable in practice by the method he had suggested, and pointed out that the isothermal inlet temperature, on which everything depended, would be difficult to obtain. There would be heat losses in the pipes and cylinders, and a transference of heat through the piston from one side to the other, and he asked how these factors would affect the results.

Professor Lea, the only other speaker on the paper, recalled an accident which had occurred to a Diesel engine at Bray, in Ireland, shortly before the war, and asked if it were possible for an effect similar to that described in the paper to have caused this accident. One of the difficulties in the way of applying the author's suggestion would be to discover materials capable of resisting the temperatures mentioned, but it might be possible to use the method to produce temperatures which were high although much lower than were attainable in the ideal case.

In his reply, Professor Watkinson pointed out that, in the table which accompanied his paper, he had given the temperatures reached when the compression was carried out according to the equation $P V^{1.3} =$ a constant, as well as under adiabatic conditions. The temperatures, in the former case, were of course much lower than in the latter, but they were still very high. In his paper at the Newcastle meeting of the Association in 1916* he had shown that it was possible to obtain self-ignition in Diesel engines with compression pressures as low as 150 lb. per square inch, by a wire-drawing process, and the pressure might have been still further reduced but for the limit imposed by the strength of the exhaust valve springs. He had then stated that it would be possible to get self-ignition at pressures of two atmospheres. The matter of obtaining a suitable material for the construction of the apparatus he left to inventors, but the difficulty might be got round in several ways. The explosion of the Diesel engine referred to by Professor Lea, he said, was due to the sticking of the fuel valve, which admitted oil to the cylinder at the wrong part of the cycle, and allowed it to be driven back into the bottles. The explosion, however, would probably not have occurred in the case cited but for the fact that compressed oxygen had been employed in the bottles for starting the engine.

Partition of the Load in Riveted Joints.

The chairman then called on Dr. C. Batho to read his paper on the partition of the load in riveted joints, in which paper the author explained his method of calculating the distribution of the load among the rivets by regarding a riveted joint as a statically indeterminate structure, and making use of the principle of least work. The author also brought forward experimental evidence in support of his theory obtained by investigating riveted joints by means of an extensometer. We print an abstract of this paper on page 314.

In opening the discussion Professor Jenkin said he regretted that lack of time prevented the full discussion of the paper, which was one of great importance. It was particularly satisfactory to notice the good agreement between theory and experiment, but he thought the distribution of the load must depend, to some extent, upon the method of closing the rivets; it would also, perhaps, vary in accordance with the actual load on the joint, being affected by the stretching of the first rivet to a greater or lesser extent.

Mr. C. E. Stromeyer, the first speaker in the discussion, said the reading of the paper might give the impression that the author's idea as to the load distribution in riveted joints was new; but such was not the case. The late Sir Edward Reed, in his book on shipbuilding, published many years ago, had shown that a large number of rows of rivets would not give a stronger joint than a few rows. It had also been shown that a treble-riveted joint might be weaker than a double-riveted one. In the speaker's own book on boiler construction he had come to a similar conclusion, and he had also estimated the loads on the individual rivets of a joint. Friction between the plates, the speaker continued, considerably affected the strength of a riveted joint, and as evidence of this he mentioned the case of a boiler plate 7 ft. 6 in. in width which had cracked inside a riveted joint with double cover plates. The crack was 6 ft. long, but the boiler had not exploded, the pressure having been supported by the friction of the cover plates. Investigation afterwards showed that the crack had opened by $\frac{1}{8}$ in. He also mentioned the case of an autoclave, in which the shell plate had cracked from top to bottom without causing an explosion. In this case

* See Engineering, September 22, 1916, page 290.

there was only one butt-strap, and he was unable to explain why the explosion had not taken place. The speaker mentioned that, some few years ago, he had investigated the distribution of stresses in screw threads and had read a paper on the subject before the Institution of Naval Architects* which he thought would interest the author, and he also referred him to an account, published in ENGINEERING† many years ago, of an extensometer he (the speaker) had devised, in which the principle of the interference of light was employed for the measurement of strains with great accuracy.

Professor Lea, who also spoke, said the application of the principle of least work to the solution of engineering problems was very interesting and important, but he asked why it was that so many existing joints had not failed, as apparently they should have done if Dr. Batho's theory were correct. He also wondered why it was that joints tested to destruction seemed to indicate a uniform distribution of shear stress on the rivets. He thought this apparent discrepancy was probably due to the fact that, in Dr. Batho's experiments, elastic extensions were measured, whereas elastic conditions would not hold up to the point of failure.

In his reply, which had to be made extremely brief, Dr. Batho pointed out that, when the end rivets were overstrained, they yielded somewhat, and the strain was passed on to the rivets nearer the centre of the joint, so that the load was more or less equalised; this accounted for the results obtained from breaking tests. His method of investigation would, however, lead to improvements in the design of large splices, for which purpose it was desirable to have an accurate theory of the behaviour of a joint under working conditions. In reply to Mr. Stromeyer he would say that he was fully aware that it had long been known that the distribution of the load among the rivets of a joint was not uniform, but he thought that his method of calculating the distribution was new. Mr. Stromeyer's remarks in the stress distribution in screw threads had interested him greatly as he had not been aware that such investigations had been carried out.

The morning meeting then terminated, and in the afternoon the Melingriffith Tinplate Works, near Llandaff, were visited by the members.

ANEMOMETER FOR MEASURING VENTILATION IN COAL MINES.

The first paper taken at the meeting on Thursday, August 26, at which Prof. Jenkin again presided, was that by Prof. J. T. MacGregor-Morris entitled "A Portable Direct Reading Anemometer for Measuring Ventilation in Coal Mines" which we reprinted on page 279 of our last week's issue. The paper was read by the author, who also exhibited the instrument and demonstrated its use as well as the method of calibrating it. Dr. Ezer Griffiths, the first speaker in the discussion which followed the reading of the paper, congratulated the author on the way he had developed his anemometer, but said he wished to call attention to some defects which had to be guarded against. The arms of the bridge, he pointed out, were all composed of wire of the same material and, with constant current, the calibration would not be the same at all temperatures. There were, however, changes of atmospheric temperature of some 50 deg. F. in mines, and, as the reading of the wind velocity depended on the watts dissipated, *i.e.*, upon C^2R, if C were kept constant R would increase by some 10 per cent. If he understood the author, a temperature correction was applied to the current to allow for the fact that the anemometer measured mass velocity, and not actual velocity, but this was unnecessary. Mining people were concerned with the weight of air circulating per unit time, which was the mass velocity. His brother had solved an analogous problem in connection with the design of a petrol gauge and found that automatic compensation for temperature effects could be obtained by making two arms of the bridge of manganin, the other two of platinum, and using an iron wire ballast resistance in the battery circuit. There was then no necessity for periodic adjustment of current and readings of temperatures. The calibration of a hot-wire anemometer, Dr. Griffiths continued, would also differ slightly in the vertical and horizontal directions for very low wind velocities owing to the disturbance of the convection current set up by the heated wire itself. He had had occasion to use a hot wire anemometer to measure the heat loss by convection from large surfaces by integration of the velocity-temperature curves. His colleague, Mr. Davies, had gone into the matter thoroughly, and the experimental difficulty was the calibration. A vertical wind channel of the Venturi type was ultimately adopted. By placing a pitôt tube in the throat and measuring the wind velocity over the section at this part, it was possible to calculate the velocities at the parts of greater cross sectional area, where the hot wire was placed, although these velocities were too low to measure by a pitôt tube directly. The great advantage possessed by the hot wire anemometer for low velocities lay in the fact that its indications varied as the square root of the velocity and the scale was open at low velocities, whereas the pitôt tube scale opened out at high velocities, its indications depending on the square of the velocity.

The only other speaker on the paper, Mr. J. S. G. Thomas, referred to a hot-wire anemometer of the type in which a pair of wires are placed one close behind the other in the air stream, and explained the characteristic features of an instrument of this type at some length. This type of instrument he said was particularly sensitive at very low velocities.

Prof. J. T. MacGregor-Morris then replied briefly saying that he considered Dr. Griffiths' use of the Venturi tube wind channel for calibrating anemometer wires very neat in view of the well-known difficulty of obtaining pitôt tube readings at low velocities. Another method which he had employed was to drive the wind-channel fan at a definite low speed. The wind speed and fan revolutions were connected by a straight-line law, and velocities calculated from a calibration curve were sufficiently accurate for the purpose. With regard to temperature corrections his method was not to employ a definite current but to read the air temperature by means of a thermometer in the anemometer head, and adjust the current to the value corresponding to that temperature, and he thought the correction sufficiently accurate for practical purposes. Mr. Thomas' remarks he considered most interesting, but they referred mainly to peculiarities which occurred at velocities lower than ½ m.p.h., whereas his instrument was used for velocities above that value and up to about 5 m.p.h.

SPECIFIC HEAT AND DISSOCIATION IN INTERNAL COMBUSTION ENGINES. INDICATOR DIAGRAM OF A GUN. HIGH SPEED PETROL ENGINES.

The chairman then called upon Mr. H. T. Tizard to read his paper on specific heat and dissociation in internal-combustion engines, of which paper we give an abstract on page 325 of this issue. Mr. Tizard read his paper leaving out the details of the calculations but explaining the principles involved, and, at the conclusion, the chairman stated that the discussion would be deferred until after the reading of the next paper by Sir J. B. Henderson and Prof. R. H. Hassé on the indicator diagram of a gun, when the two papers would be discussed together with that read by Mr. Ricardo on the previous morning. The joint paper by Sir J. B. Henderson and Prof. Hassé was then read by the latter.

The paper dealt firstly with the calculation of the temperature of explosion of the gases given off from the burning of the British service propellant M.D. cordite. The calculation is based on the theory of the variation of the specific heat of the gases with temperature and of the dissociation of gases at high temperatures. The fundamental reaction, in the case of cordite, is the water gas reaction $CO + H_2O = CO_2 + H_2$, and it is shown that the temperature of explosion is of the order of 3,140 deg. Cent. absolute. This theoretical temperature is compared with the result deduced from the experiments of Sir A. Noble on M.D. cordite, in which he showed that the relation between the maximum pressure obtained and the specific volume of the charge is of the form $p\,(v-b) = \text{constant}$, where p is the pressure, v the specific volume of the gas and b the specific volume of the solid cordite. Interpreting the constant in the above equation in terms of the modified Boyle's law equation, it is equal to $R\,\theta_0$, thus giving θ_0, the temperature of explosion. The agreement between theory and experiment is within the limits of error of the experimental measurement of the pressure. The energy content of the gases is then calculated as a function of the temperature and the result is applied to the calculation of the curve of adiabatic expansion.

The practical application of the theory to the explosion in a gun is made in two ways. The first is by taking the case in which the pressure is supposed to rise instantaneously to the maximum allowed in the gun, say 20 tons per square inch, before the projectile moves, to remain at this value while the remainder of the charge is burning and the projectile moves, and finally to decrease in accordance with the curve of adiabatic expansion of the whole mass. The indicator diagram for this case gives the maximum amount of work that could be obtained from the explosion and is called "the ideal indicator diagram." The second method takes into account the production of fresh gas from the burning propellant in accordance with the law of burning given by Mansell, Petavel and others. It is possible to allow for the resistance of the driving band by supposing the pressure to rise to a definite amount before the projectile moves. In this way the experimental and calculated maximum pressures may be made to agree. The total work done on the projectile may be calculated from the indicator diagram, and after an allowance has been made for the losses of energy in heat, friction, &c., the muzzle velocity may be calculated. According to the results obtained 92 per cent. to 95 per cent. of the energy is converted into kinetic energy in the projectile, so that less than 8 per cent. is spent in heat and other losses.

The theory given in the paper was worked out before and during the war, and was published with the consent of the Admiralty.

Sir J. B. Henderson, invited to speak by the chairman, mentioned that the work discussed by Prof. Hassé was of a theoretical nature, but until a satisfactory theory had been obtained it would not be possible to make much further advance. In 1910, he continued, Planck had published his quantum theory, which stated that energy was not indefinitely devisible, but existed in fundamental minimum quantities. On these lines valuable deductions had been made as to the distribution of energy in the spectrum, and he (the speaker) had read a paper at the York meeting of the Association applying the principle to the case of radiation pyrometry. Later it had been applied to the consideration of explosions in closed vessels, and a remarkable agreement obtained between theory and experiment, the errors between theoretical and actual curves being less than the differences between two sets of experimental values. During the war, with Prof. Hassé's assistance, the subject had been developed further, and the application to guns had given remarkably consistent results. He considered that the quantum theory, which applied so satisfactorily to the theory of explosions, would also apply to internal combustion engines. With regard to Mr. Tizard's paper he thought the figures given for specific heats could not be experimental, as it was not possible to obtain these experimentally at temperatures above 1,500 deg. C. At higher temperatures they must all be obtained by explosion methods, and would not be accurate until a satisfactory theory was obtained.

Sir Charles A. Parsons, who followed, raised the question of the maximum pressures produced by explosions, and mentioned that, in Sir Andrew Noble's experiments, the maximum pressures given were of the order of 70 tons per square inch, whereas he thought they must be much higher. As evidence of this he said the detonation of a piece of instantaneous fuse, which consisted of a piece of lead tube filled with trinitrotoluene, was sufficient to indent a piece of hardened steel on which the fuse was laid, and, if a loop of fuse were detonated in the same way, the effect was much greater at the

* See ENGINEERING, vol. CV, page 359.
† See ENGINEERING, vol. XXX, page 337.

point where the two explosion waves met. The pressure required to produce this effect would be of the order of 200 or 300 tons per square inch. He doubted if explosion pressures measured in closed chambers gave the real maximum pressures produced by the explosives.

Dr. N. V. Sidgwick, the next speaker, enquired what light the figures given by Mr. Tizard threw on the relative values of different fuels for internal-combustion engines, and he also asked Sir J. B. Henderson to explain to what extent the nitrogen present at the high temperatures and pressures of explosions existed in the form of oxides of nitrogen. The first question was replied to by Mr. Ricardo, who stated that the efficiency of a fuel was directly proportional to its calorific value. Another speaker, whose name did not transpire, enquired why Mr. Tizard did not use the free energy of the fuels in his comparisons rather than the heat of combustion, and Prof. Hudson Beare also asked if the values of $\gamma - 1$ in the equations used by Mr. Tizard applied only to the particular fuels experimented with, or whether they could be used for other fuels, such, for instance, as coal gas.

Prof. Watkinson asked if Mr. Ricardo took indicator diagrams in his experiments and determined the maximum pressures developed under various conditions. It appeared, he said, that the indicated horse-powers had been determined by differences, but he presumed that some diagrams had been taken. He would also be interested to know how the temperature of the stagnant water in the jackets had been arrived at and asked whether steam had been allowed to blow off; Mr. Ricardo replied that this was the case.

In his reply Mr. Tizard took exception to the views expressed by Sir J. B. Henderson as to the quantum theory, and said he did not consider the theory could be applied, at present, to the determination of specific heats at high temperatures, though it might be possible to do this in the future. He also disputed the statement that his determinations of specific heats were not experimental; the process of obtaining them, he admitted, was a complicated one, but it was certainly experimental. In reply to Sir Charles Parsons, Mr. Tizard said he realised the difficulty of measuring detonation pressures accurately, and added that, in engine calculations, it had been found that the maximum velocity of the detonation wave was rather less than the velocity of sound in aluminium. To the speaker who had raised the question of the use for purposes of comparison of the free energy, or the heat of combustion of fuels, Mr. Tizard replied that he thought it made but little difference, and he enquired of Sir J. B. Henderson how the heat losses in a gun had been estimated in his paper. These losses, Mr. Tizard thought, must be much greater than the corresponding losses in a petrol engine, and would therefore need to be taken into account in gunnery calculations.

Mr. Ricardo then replied to the speakers on his paper, stating that he had endeavoured to use an optical indicator in his experiments, but without success. A gauge had been used to determine compression pressures, but this was not suitable for measuring explosion pressures. He had also used a sampling valve to determine pressures at any two points in the cycle, but this could not be used for high pressures. Mechanical losses, he said, had been determined by motoring the engine after running it at full load for a sufficient time for the temperatures to become normal.

In his reply Sir J. B. Henderson said he thought the difference between Mr. Tizard and himself was really one of definition, but he regarded experiments on specific heats at temperatures higher than 1,500 deg. C., as of little value. With regard to the heat losses in guns he said the proportional loss was much less than that of a petrol engine. In a gun the combined loss due to radiation, convection and friction was less than 5 per cent. He had not time to go fully into the point raised by Dr. Sidgwick, but it was fully dealt with in the gunnery manual which would be published very shortly.

Steam Action in Simple Nozzles.

After a vote of thanks to the authors of the three papers discussed above had been carried, Prof. A. L. Mellanby was called upon to read the paper on steam action in simple nozzles of which he was the joint author with Mr. W. Kerr. This paper is reproduced in full in this issue (see page 310). Prof. Mellanby then gave a brief account of the experiments described in the early part of the paper, after which Mr. Kerr explained the latter part dealing with the effects of the form of the nozzle. Prof. Jenkin, at the conclusion of the paper, said he regretted that the very rapid delivery necessitated by the lateness of the hour had rendered the matter somewhat difficult to follow, but, personally, he greatly favoured simple methods in experiments. He had himself carried out some simple, but carefully conducted, experiments on nozzles, and these had fully confirmed the results obtained by Prof. Rateau. It was unfortunate that so little time remained for the discussion of the authors' valuable paper.

Sir J. B. Henderson, the first speaker, said he was coming more and more to the conclusion that the fundamental point was that the energy at the throat was not the same as that in the chamber, as was usually assumed to be the case. There was apparently more energy at the throat than in the chamber, and this, he thought, might be explained by the existence of a stationary wave. A stationary wave would act as a source of energy, and we had no right to assume that this did not exist.

Prof. Lea, the only other speaker, said he had not had time to assimilate the points brought forward in the paper, but he thought it doubtful that the simple equation $PV^n = \text{constant}$ could hold for the complicated conditions in a nozzle and there might be a good deal in this. In conclusion he wished to pay a tribute to the authors for the valuable work they had done.

The Chairman, in thanking the authors, mentioned that a Committee of the Institution of Mechanical Engineers was now studying the question of nozzles. The matter was difficult and important, and he hoped the committee would give due consideration to Prof. Mellanby's and Mr. Kerr's paper. There being no time for the authors to reply to the speakers on the paper the meeting then adjourned. In the afternoon the members visited the Dowlais Works of Messrs. Guest, Keen & Nettlefolds, Limited, at East Moors, near Cardiff.

Pneumatic Conveying of Materials.

The first paper on the programme for Friday, August 27, which was the last meeting of the session, was that by Prof. W. Cramp, describing his experiments relating to the conveying of grain, and other materials, by pneumatic means. We publish an abstract of the paper on page 330 of this issue, so that no further explanation of its contents is necessary here. In opening the discussion, which followed the reading of the paper, the Chairman, Prof. Jenkin, remarked that the author had not touched upon the conveying of grain along horizontal pipes, and appeared to have confined his experiments to vertical pipes. He asked what was the density of the grain in the pipes; did it travel in the form of plugs, or pistons, or was each grain separate? The author had referred to the conveying of coal by pneumatic means, and Prof. Jenkin asked if the coal was in the form of dust or small nuts. The author's research work, he added, appeared to have been very successful, and the agreement of the theory with the practical results obtained was extremely good.

The first speaker, Mr. J. S. Wilson, asked the author whether, in estimating the efficiency of the system, he had considered the friction of the grain on the inner surface of the pipe, and Mr. N. C. Godby, who followed, said he had had some experience with the working of pneumatic grain elevators in Cardiff and he would like to know what was the highest efficiency Professor Cramp had encountered in practice. The efficiency, the speaker continued, varied according to the quality of the grain. With No. 1 Manitoba wheat, he found that it required about 1·2 h.p. per ton per hour raised 40 ft. With regard to the Chairman's query as to the handling of coal by pneumatic elevators he could reply that he had actually discharged coal in pieces up to 3-in. cube from a barge by this means. The drawback to pneumatic elevators was their low efficiency, and practical men looked to scientific workers to increase this efficiency. With regard to the matter of conveying grain in horizontal pipes by means of an air current, referred to by the Chairman, he did not think that investigations were likely to be very fruitful. The problem of moving grain in a horizontal direction had been already solved by means of the band conveyor. He rather thought that the softer varieties of wheat would suffer some damage in a horizontal pipe.

Professor Watkinson, the only other speaker, said he had had some experience in conveying coal dust by pneumatic means, and had got over the difficulty of conveying it in horizontal pipes by continuously rotating the latter. He enquired if Professor Cramp had tried the effect of feeding the grain into a converging tube at the inlet end, so that the grain would be accelerated as the air velocity increased, and also of using a diverging tube at the discharge end to bring the grain gradually to rest. He thought arrangements of this kind would give increased efficiency.

Professor Cramp then replied to the speakers, stating that none of his experiments referred to horizontal pipes although he hoped to carry out some work on these in the future. He could state, however, that the power required to transport a given quantity of material along a horizontal pipe was less than that required for the same length of vertical pipe. He mentioned this because some makers had stated that it was very much easier to elevate than to convey grain by pneumatic means. Time did not permit him to say much on this part of the subject, but he thought it might interest the meeting to know that, before the war, the Germans had endeavoured to investigate the flow of grain in horizontal pipes by means of kinematograph photographs, but had been unsuccessful owing to the very rapid movement of the grain. He had used a horizontal tube of glass, 30 ft. long, to watch the movement, and had found that the grain kept more or less in the centre of the pipe. In answer to the Chairman's query he would say that the grain did not move in the form of plugs or pistons, and, if such occurred, the action would cease. The density of the material was a matter of importance in connection with the efficiency of the system, and, in general, the highest efficiencies could be obtained with the lightest materials. No. 1 Manitoba wheat, being very clean, was easy to elevate, and had been used in all the tests described in the paper. English wheat, which was wetter and heavier, could not be dealt with so efficiently, but materials such as malt were more easily handled than wheat, while maize, being heavier, gave lower efficiencies. His answer to Mr. Wilson was that the friction had been considered in obtaining the efficiencies, and to Mr. Godby's query as to the highest efficiency obtained he answered that an efficiency of 40 per cent. could be obtained with No. 1 Manitoba wheat, although this figure was not approached by any plant at present in use. The figure given by Mr. Godby as the power required for a certain duty, was about the average result, but he expected to be able to reduce this to about one-third. With regard to conveying grain in horizontal pipes he thought this would be done, as it would be a disadvantage to change over from one system to another as would be necessary if band conveyors were used. The injury to the grain in horizontal pipes, he thought, would be negligible, and it was fortunate that the highest efficiencies were obtained with low air velocities at which the damage was least. The rotating tube referred to by Professor Watkinson, was very ingenious, but the pipes for conveying grain would generally, he thought, be too long to be rotated in this way, and, moreover, they were not usually straight. He had tried the effect of diverging and converging nozzles and had obtained some increase of efficiency by this means, but he thought the improvement hardly sufficient to justify the additional complication.

Airships for Slow-Speed Heavy Transport.

The Chairman then called upon Wing-Commander Cave-Brown-Cave, to read the next paper on the programme, the subject of which was "Airships for Slow-Speed Heavy Transport and Their Application to Civil Engineering." The paper, which we reprint on page 331 of this issue, was read by the

author, who, before doing so, explained that his object in reading it was to obtain from the members present additional suggestions as to possible applications for airships. At the conclusion of the paper, Professor Jenkin remarked that his own war work had had more connection with aircraft of the heavier-than-air type than with airships, and he had not had much faith in the utility of airships for the class of work suggested by the author. Commander Cave-Brown-Cave had, however, made out such an excellent case for airships that he was inclined to change his views. He thought that surveyors dropped by a wire from an airship into otherwise inaccessible parts would find the experience somewhat exciting, but he had no doubt that the class of men engaged in such work would be quite willing to take the risk.

Mr. Arnold Lupton enquired what was the cost of an airship having a length of 600 ft. to 700 ft., and also asked what would happen if after having landed a surveying party an airship was prevented by adverse winds from returning to pick them up.

Professor Lea, the next speaker, said the use of airships in connection with surveying work and railway construction was extremely interesting. The latter would be greatly facilitated if working depôts could be put down at various parts, as it was difficult and expensive to work always in one direction. He thought the necessity for putting down hydrogen plants to supply the airships might be a rather serious objection to their employment, but probably the plant required for a few small airships would not be very extensive. He asked the author if he were confident that the difficulty of obtaining satisfactory constructional materials for airships had been overcome, and whether the materials in use were reliable without a repair staff; engine troubles, he added, had also to be considered. He thought, in connection with railway construction, that large aeroplanes could do the work as well as airships, provided a suitable landing ground were available. There might, he concluded, be a real future for rigid airships, but he thought that, before they could be used for the class of work suggested by the author, more assurance as to the constructional details and engining of the ships would be needed.

The only other speaker on the paper was Professor Cramp, who referred to the difficulty which might arise in connection with the towing or suspension ropes. These long ropes, he said, would hang down approximately in the form of a parabola and would swing about in a wind quite out of the control of the airship crew. He asked how such a difficulty would be overcome.

As the time available was short the Chairman called on Wing-Commander Cave-Brown-Cave to reply to the points raised in the discussion. To Mr. Lupton the author replied that the cost of the "R. 34," which was built in very exceptional circumstances, amounted to £400,000, but the figure given by Air-Commodore Maitland for a similar ship built under normal conditions was about half as much. He did not think it at all likely that an airship would be unable to return to pick up a surveying party. Under existing conditions a party had to subsist for weeks, or months, on the supplies they could carry with them, while they could be much better equipped if taken to their work by an airship. It was also possible to select a period of the year at which storms were not prevalent, and on any day there were periods of calm at sunrise and sunset of quite sufficient duration to pick up the party. In answer to Professor Lea the author stated that the gas plant would be situated at the base, and that most of the ordinary running repairs were carried out by the airship crew. With regard to the deterioration of materials, he thought Professor Lea might be reassured, as fabric had been found to withstand the climate of Egypt for a year without any serious loss of strength. In order to use aeroplanes, the author stated, the construction of the necessary aerodromes would be almost as serious an item as the construction of the railway itself, and even the keeping of them free from the luxuriant tropical growths would be a formidable business. The effect of engine failure in an aeroplane travelling over tropical forests would also be much more serious than a similar failure in the case of an airship. With regard to the effect of the slack wire referred to by Professor Cramp, the author anticipated no difficulty. For towing, he said, a wire about 600 ft. in length would be required, so that it could not hang down more than 300 ft., and, as an airship would probably fly at about 2,000 ft., the wire would be nowhere near the ground. He also added that it was not always realised, in this connection, that there could be no cross-wind force. The airship was always head on to the wind, so that there would be no tendency for the wire to be blown laterally.

Long-Distance Radio-Telegraphy.

After thanking Wing-Commander Cave-Brown-Cave for his interesting and suggestive paper, the Chairman called on Professor G. W. O. Howe to read his paper on the efficiency of aerials and the power required for long-distance transmission. As time was pressing, Professor Howe briefly explained the points more fully dealt with in his paper, which we hope to reprint in a later issue, addressing himself rather to laymen than to persons fully familiar with recent research in radio-telegraphy. In conclusion, he pointed out that the great discrepancies in the calculated values of the power required for long-distance transmission indicated the necessity for further research, mentioning that, as far as their present knowledge went, the power required to transmit messages a distance of 10,000 km. might be either 100 kw. or 20,000 kw. or anything between these two limits.

In declaring the paper open for discussion, the Chairman mentioned that the President of the Association, Professor W. A. Herdman, had referred in his address to a possible new and larger "Challenger" expedition, which might be organised to investigate problems in oceanography, and the sections had been invited to suggest other problems suitable for study by such an expedition. The Engineering Section thought that the expedition would provide an excellent means for investigating radio-telegraphic signals over much greater distances than had been possible in the experiments by Austin referred to in Professor Howe's paper. Possibly other problems to be investigated might be suggested by the section.

Professor Cramp congratulated the author on the paper and on his method of explaining it, and enquired whether the effect of the ionized layer in the upper atmosphere had been considered, and whether it had been regarded as a reflector or a refractor of the waves. He thought it possible that something might be done to improve the efficiency of transmission by employing reflectors with shorter waves. In Table VIII of the paper, he noticed a range of wave lengths from 5 km. to 30 km. for distances varying from 1,000 km. to 10,000 km., and he thought the adjustments necessary to alter the wave length to this extent would not be feasible in practice.

Another speaker, whose name was not mentioned, enquired whether it were not a fact that, but for the ionized layer of the atmosphere, the signals would travel off tangentially, so that long-distance transmission over the surface of the earth would be impossible.

The only other speaker, Professor Watkinson, said he understood that signalling was much better at night than during the day, and he enquired what was the difference in the power required for a given distance. He suggested that an ionized layer of air might be formed artificially in the neighbourhood of wireless stations to act as a reflector for the waves.

In replying to the discussion Professor Howe explained that the figures given in Table VIII of the paper were not intended to indicate alterations in wave length, but were intended to apply to two stations working at fixed distances apart. With regard to the use of short wave lengths with reflectors, he thought it would be difficult to get sufficient power into the aerial with short waves. The absorption also increased rapidly as the frequency increased, so that the signals would be rapidly damped out. Moreover, reflectors, even for short waves, would have to be very large, as they would be useless unless made to dimensions of the order of several wave lengths, and the shortest waves used had a length of 600 metres. To the speaker who enquired about the effect of the ionized layer in the atmosphere, he replied that it was quite correct that the propagation of waves round the earth would be very small but for the existence of this layer. With regard to the relative strength of signals in daylight and at night he said the difference was not very much for long wave lengths; the difference, in fact, was less than the variations arising from atmospheric disturbances. To Professor Watkinson's suggestion as to the formation of an artificial ionized layer in the atmosphere he replied that he could conceive of no practical method for producing such a layer.

Rock Removal in the Rio Guadiana.

The time allotted to Professor Howe's paper having then elapsed, the Chairman asked Dr. J. S. Owens to read his paper, which was the last on the programme. This paper, we may briefly explain, describes the removal by drilling and blasting of about 11,000 tons of rock reefs from the bed of Rio Guadiana at Pomaron, the port of the San Domingos Mines. At this place the rise of the spring tide amounts to 11 ft., the maximum normal current of the river to about 3 knots, and the maximum depth over the reef to 30 ft. Drilling was carried out from a floating barge using a 5-in. Ingersoll drill operated by steam, the barge being kept stationary by means of four spuds which could be raised or lowered, as required, by winches. Charging was done, without divers, by using specially prepared "sausages" of dynamite which were dropped through a pipe into the drilled holes and exploded electrically in groups of about eight at a time.

At the conclusion of the reading of the paper the Chairman called attention to the fact that insufficient time remained for a full discussion, but he invited any members who wished to ask questions to do so. To one speaker who enquired what was the nature of the drill used, Dr. Owens replied that it was an ordinary rock drill which worked by giving a number of blows in rapid succession, with a slow rotary motion in addition. The cutting face of the drill, he said, was in the form of a cross, and he added that the angle of the cutting edges was a matter of considerable importance. In the drill heads first employed, he said, the cutting angle had been too sharp, and this had caused the drill to jam in the hole. The reason for this was that with a sharp cutting angle the rock was splintered, and the comparatively large chips produced were the cause of the jamming. With a blunt cutting edge the rock was pulverised, and the fine material produced in this way was easily washed out of the hole.

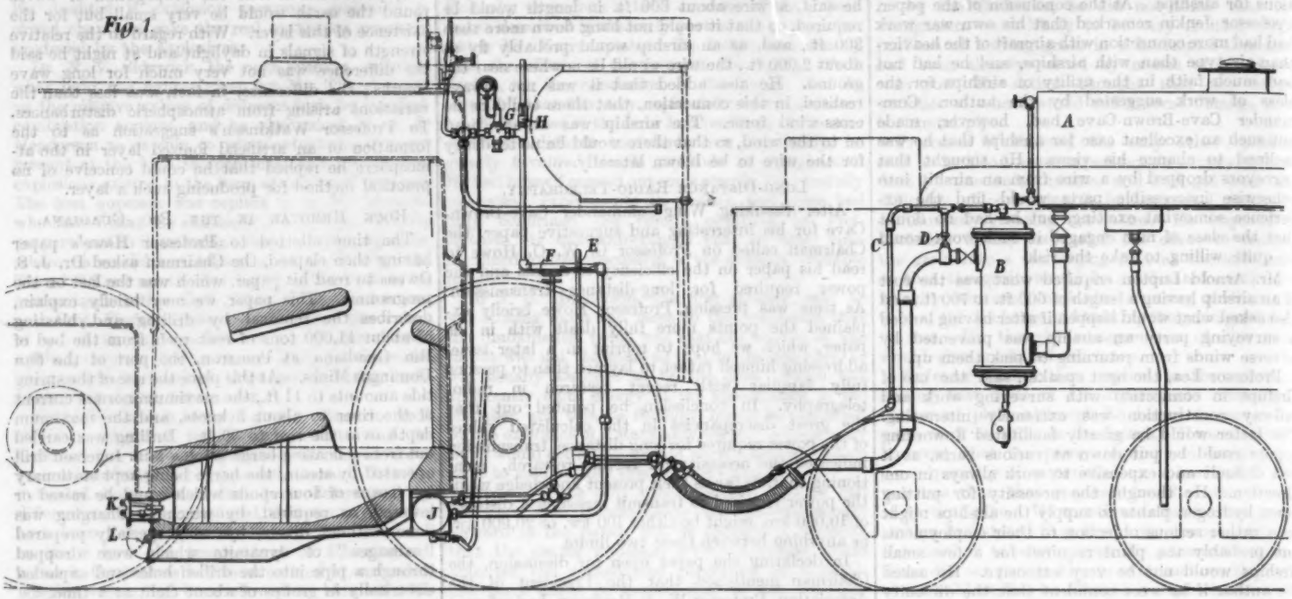
The meeting, and the work of the session, then terminated with a vote of thanks to the Chairman, proposed by Professor Lea. In the afternoon the section visited the surface plant of the Great Western Colliery, at Pontypridd, an interesting feature of which is the large electric winding engine.

(To be continued.)

Lloyd's Aviation Record.—A matter of considerable importance in connection with the development of civil aviation in this country is the establishment of a Lloyd's Aviation Record, which has recently been approved. Some time ago, the Committee of Lloyd's, recognising the importance of aviation insurance, set up a sub-committee on aviation, assisted by a technical committee, these committees including representatives of the aerial transport companies, aircraft constructors, and underwriters. Adequate insurance facilities are obviously of the utmost importance in connection with civil aviation, and to provide such facilities certain essential information must be collected and recorded in a convenient form so as to be readily available for reference. The purpose of the Aviation Record is to provide this information, and the first part, which will shortly be issued to subscribers, will deal with aircraft and pilots; other parts, to be issued subsequently, will be devoted to technical *personnel*, aerodromes, alighting waters, air routes, foreign laws, &c. The record will be international in character, and steps are being taken to establish Lloyd's aviation agents abroad, as well as at home. It is not intended to make the Record more than self-supporting, but aircraft constructors, aerial transport companies, and aviation underwriters desirous of utilising the information afforded, will be required to subscribe to its maintenance. Pilots wishing to be enrolled on the Record can obtain an application form from The Secretary, Lloyd's, Royal Exchange, London, E.C. 3, and owners of aircraft desirous of ensuring that correct particulars of their machines are included can obtain the necessary form from the same address. The information given will be recorded free of charge.

THE SCARAB SYSTEM OF OIL FUEL BURNING ON LOCOMOTIVES.

Fig. 1.



FOR some time a locomotive has been running successfully on the London and North-Western Railway fitted with oil fuel on the system introduced by the Scarab Oil Burning Company, Limited, 28, Charles-street, Haymarket, S.W. 1. This system has already been applied in other directions, but this is the first instance of a locomotive being fitted with it in this country. In general arrangement, as fitted to an engine of the "Precursor" type, the system does not present any very unusual features, the chief interest being in the form of burner adopted.

Fig. 1 shows the general arrangement of the system. The fuel tank on the tender is shown at A. B is a steam heater which, however, is not always needed, though it has to be provided for working through the cold weather. A steam trap is fitted below to keep it drained. The pipe C conveys steam to the heater, while a branch D is arranged so that the oil pipes can be blown through when required. The oil and steam controls for the burner are side by side at E and F, in the cab. Steam is taken from the boiler through a reducing valve G, to a receiver J, the object of which is to damp any pulsations which may occur through the action of the reducing valve. A relief valve H is fitted to the steam supply to prevent the pressure rising beyond the desired amount. The burner itself is shown at K, arranged below the front end of the fire-box. Details of the burner are given in Figs. 2 to 4. The ordinary coal grate is abolished, and the usual ash pan replaced by a firebrick lined box with a low arch above, and, in addition, a further fire-brick baffle to break up the flame on its way to the tubeplate. Air supply is arranged through the burner sleeve, while supplementary air is provided through an adjustable damper, L, below, which admits air direct to the combustion chamber, and also indirectly to it through holes in the fire-brick floor. A further supply is admitted through a passage below the floor to a point at the back end of the fire-box. It has been found that one large burner suffices for the ordinary standard gauge type of locomotive fire-box, though the London and North-Western engine has been fitted with one large and two smaller burners, the latter being used for maintaining steam while standing.

The burner itself is shown in Figs. 2 to 4. In these drawings the controls are placed at the burner, but as fitted to the locomotive type of boiler these are arranged in the cab as indicated in Fig. 1. This does not affect our description of the burner in any way. The burner fixture or mounting consists of a sleeve within which are two tubes. The upper tube, set on an incline of 1 in 8·15, is for the oil supply. This is fed by gravity on to a fan-shaped sloping tray seen in section in Fig. 2, in plan in Fig. 3, and end elevation in Fig. 4. This tray is arranged with a number of small ribs at its edge, so that the oil is distributed over the lip as evenly as possible. The lower tube is for steam supply. This ends in a fitting shown in section in Fig. 2, the lip of which rises to meet the underside of the oil tray, leaving, as shown in Fig. 4, a long aperture, $\frac{1}{16}$ in. deep and about $2\frac{1}{2}$ in. wide for the steam to issue from. The steam catches the oil as it falls over the lip of the tray above and atomises it so as to convert it into a form which is easily ignited. It may be pointed out that the oil opening in this burner is not restricted in any way in parts exposed to the heat of the furnace, thus reducing risks of choking from carbonisation.

Fig. 2.

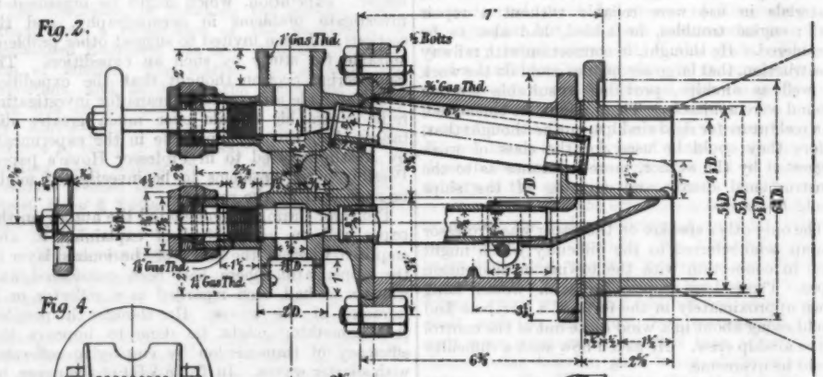


Fig. 4.

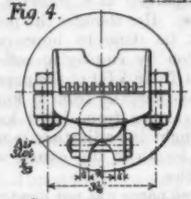
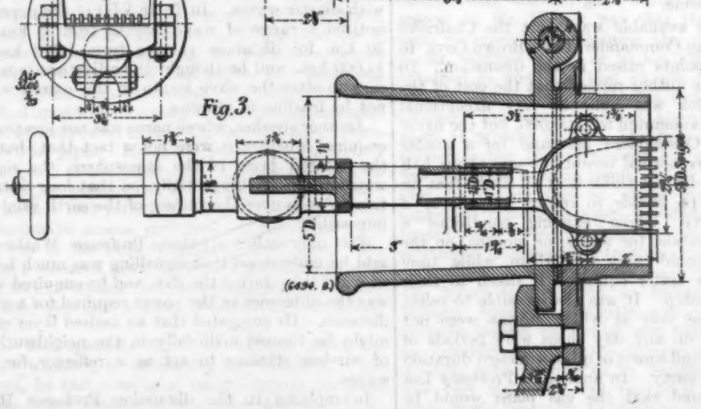


Fig. 3.



The London and North-Western engine has been fitted with this apparatus for some weeks, and has been on all classes of service from piloting and stopping trains to express service. No difficulties have been experienced in maintaining steam. We are informed that the consumption works out at about 10 lb. of oil per 100 tons per mile, and that no time has been lost up to the present owing to steaming delays.

PROHIBITION OF EXPORT OF WOOD FROM SWEDEN.—The limited export of coal into Sweden during the last few years has been such that industry and the great consumers of fuel have begun to use wood instead of coal to a very large extent. In consequence of this the supply of wood for household purposes has been diminished; and it is feared that the situation may become critical in the coming winter. In order to prevent the country's stock of wood from going abroad under such circumstances there has been issued a prohibition of the export of wood and certain groups of hewn timber and round timber. The Government is also preparing measures to increase the production of wood. The organisation which existed for this purpose during the war, the Fuel Commission, has been wound up, but it should be easy to reconstitute it in case of need.

SPECIFIC HEAT AND DISSOCIATION IN INTERNAL-COMBUSTION ENGINES.*

By H. T. TIZARD and D. R. PYE.

1. THE British Association Committee on Gaseous Explosions devoted a good deal of attention before the war to the question of the specific heat of the working fluid and the possible effects of dissociation of carbon dioxide and water vapour at high temperatures. Unfortunately this work was interrupted by the war, and there has been in recent years very little advance in the thermodynamical theory of internal-combustion engines. On the other hand there have been great practical advances, and the actual efficiency of a modern high-speed engine is higher than the theoretical efficiency calculated on the old specific heat figures of Clerk and Langer, even if no allowance is made for loss of heat. The relative advantages of different fuels; increase in efficiency to be expected from an increase in compression ratio; and the reasons for the change in power with different "mixtures," are all problems which have not yet been satisfactorily solved. For these reasons the authors were led to take up the subject afresh.

2. A method for calculating thermal efficiency from a knowledge of specific heats was worked out very completely by the late Professor Hopkinson in his paper on the "Thermal Efficiency of Gas Engines," but all work on these lines has suffered under two great disadvantages: (1) The specific heats of the gases concerned were not known at all accurately above 1,500 deg. C.; (2) the dissociation of CO_2 and H_2O in the cylinder was unknown, and no attempt has been made to separate the two effects of specific heat and of dissociation. As to the first point, there is ample evidence to show that the maximum temperature reached in a petrol engine is of the order of 2,500 deg. C. As to the second point, the Committee on Gaseous Explosions pointed out rightly that it was the "apparent" specific heat that was of primary importance for the theory of engine efficiency and this included any effects of dissociation. But the dissociation of CO_2 and H_2O is accompanied by an increase in the number of molecules, and therefore its extent depends considerably upon the pressure as well as the temperature. Further, since they have one dissociation product in common, namely, oxygen, dissociation in a mixture of the two is not the same as when they are separate; the extent of the dissociation of each will in fact depend on the ratio of the amounts present, and the "apparent" specific heat of a mixture may be very different to the sum of the "apparent" specific heats of each measured separately. The only possible way to attack the problem is to find the true specific heats, and to measure the dissociation under definite conditions, from which it is possible to obtain sufficient data to calculate equilibrium conditions in any mixture.

3. Sufficient data already exist for this purpose. A number of experiments, both in the dissociation of CO_2 and H_2O, and on the true specific heats of gases at high temperatures have been carried out in Nernst's laboratory in Berlin, with the primary object of testing recent developments in chemical thermodynamics. The following tables give the results of most importance for our purpose.

TABLE I.—*Mean volumetric heats between* 100 *deg. and* 3000 *deg C. in gram-calories per gram-molucule.*

100 Deg. C. up to	500 Deg. C.	1,000 Deg. C.	1,500 Deg. C.	2,000 Deg. C.	2,500 Deg. C.	3,000 Deg. C.
Nitrogen	5·17	5·28	5·50	5·75	6·00	6·30
Water vapour ..	6·25	6·94	7·64	8·42	9·71	11·2
Carbon dioxide ..	8·25	9·55	10·07	10·50	10·87	10·95

TABLE II.—*Dissociation of CO_2 and H_2O at different temperatures and pressures (expressed in percentages).*

CO_2.

Temperature.	Pressure.			
	0·1 Atm.	1·0 Atm.	10 Atm.	100 Atm.
1,500 deg. C. ..	0·1	0·05	0·022	0·01
2,000 deg. C. ..	4·35	2·05	0·96	0·45
2,500 deg. C. ..	33·5	17·6	8·63	4·1
3,000 deg. C. ..	77·0	55·0	32·0	17·0

H_2O.

Temperature.	0·1 Atm.	1 Atm.	10 Atm.	100 Atm.
1,500 deg. C. ..	0·04	0·02	0·01	0·004
2,000 deg C. ..	1·25	0·58	0·27	0·125
2,500 deg. C. ..	8·8	4·2	2·0	0·93
3,000 deg. C. ..	28·4	14·4	7·1	3·3

4. It is assumed in the first place that the only molecular species present after an explosion and during the expansion are CO_2, H_2O, CO, H_2, O_2, N_2, and, at the high temperatures reached, the reaction velocity is such that chemical equilibrium is always maintained throughout the working stroke. There is considerable evidence in favour of the substantial accuracy of this assumption; if true, and if the gas laws held at those high temperatures, which is also extremely probable, the pressure and temperature when the explosion takes place, and at any point during the expansion, may be calculated from the chemical equation representing the combustion and from the dissociation constants of CO_2 and H_2O, deduced from the figures given above. Taking the case of mixtures of pure benzene with air, the shape of the power curve is first investigated on the assumption that dissociation takes place. The composition of the gases after exploding a rich mixture can be calculated from a knowledge of the "water gas" reaction,

$$CO_2 + H_2 = CO + H_2O$$

It is shown that the power curve should show a sharp maximum when benzene is present in the correct proportion for complete combustion to CO_2 and H_2O, and should fall off steadily for both weaker and rich mixtures. This is contrary to observations, which in itself is evidence of "dissociation." When dissociation is taken into account it is shown that the power should remain constant to within about 1 per cent. for mixtures ranging from the correct mixture to about 30 per cent. rich mixtures. This is entirely confirmed by experiment. It was further predicted that the same curve of an engine running on a paraffin mixture should fall off more sharply with the richness of mixture than if benzene were used. This has also been confirmed by experiments on Mr. Ricardo's experimental engine.

5. Maximum thermal efficiencies in practice are obtained with mixtures so weak, that any further weakening results in mis-firing. Experiments by Watson and others have shown that this occurs when the amount of fuel present is only about 80 per cent. of that required for complete combustion of the air. It is shown that if the compression ratio be five to one, the theoretical efficiency, if there is no heat loss, should be 38 per cent. of the heat of the fuel. Indicated thermal efficiencies as high as 70 per cent. of the "air cycle efficiency" (= 33 per cent.) are said to have been obtained in engines working at this compression ratio. The highest thermal efficiency under these conditions that the authors have been able to obtain is 32 per cent. of the heat of the fuel. The difference between the calculated and observed values corresponds to a loss of heat during the working stroke of about 13 per cent. of the heat of the fuel. Since the total loss of heat to the cylinder jackets was found to be about 25 per cent., the correspondence between calculated and observed values must be considered very satisfactory. It is interesting to note that with weak mixtures the theoretical efficiency is about the same whether the gases are assumed to be dissociated or not. The effect of dissociation (which is about 20 per cent. of the CO_2 present at the maximum temperature) is to lower the maximum temperature, without affecting appreciably the work done on expansion.

6. The maximum temperature calculated for a benzene air mixture is 2,700 deg. C. (initial temperature of charge = 100 deg. C.). The increase in molecular volume in such a case is about 6½ per cent., and the maximum pressure, assuming a volumetric efficiency of 80 per cent. should, therefore, be

$$5 \times 0{\cdot}8 \times 1{\cdot}065 \times \frac{2,973}{373} = 34 \text{ atmospheres}$$

= 510 lbs. per square inch.

If the loss of heat before the attainment of maximum pressure is 10 per cent., the maximum pressure would be about 460 lbs. per square inch, which corresponds closely to the maximum pressures observed in practice, but the calculation is only approximate, and assumes an instantaneous rise in pressure. The maximum temperatures for a paraffin petrol air mixture are considerably lower.

7. The theoretical efficiency at different compression ratios has also been examined. It is found that for a "correct" mixture, which in practice is about the weakest mixture giving maximum power, this efficiency can be expressed empirically by the expression

$$1 - \left(\frac{1}{r}\right)^{0{\cdot}358}$$

and that the *maximum* efficiency (20 per cent. weak mixture) can be expressed by the formula

$$1 - \left(\frac{1}{r}\right)^{0{\cdot}5}$$

where r = the compression ratio. The latter gives a real standard of comparison by which actual performance can be judged. It assumes no loss of heat, during the working stroke, but takes fully into account the nature of the working fluid. It is interesting to note that the investigation led to the conclusion that the rise in efficiency with increase in compression ratio should be much greater in proportion than that predicted from the air cycle formula.

Experiments undertaken with Mr. Ricardo's engine, using benzene as fuel, fully bore this out. The following table gives some of the results:—

Compression Ratio.	Air Cycle. Efficiency.	Observed Efficiency.	Ratio.
4 to 1	0·425	0·275	0·65
5 to 1	0·475	0·316	0·665
7 to 1	0·540	0·372	0·655

The rise in efficiency at maximum power would appear to be still greater in proportion, but no experiments have yet been made to test this, and indeed it would be difficult to obtain accurate figures.

8. As regards maximum power with different fuels, it is shown that when all factors are taken into account, the maximum power with perfect distribution should be the same within 1 per cent. for any kind of hydrocarbon fuel, if the initial charge temperature (or volumetric efficiency) and the compression ratio are constant. The maximum power with alcohol should be slightly lower, but as the latent heat of alcohol is high, the charge temperature in practice is lower, and the maximum power reached is the same, or slightly higher, than that reached with hydrocarbon fuels. These conclusions have also been confirmed by experiment.

9. Finally it is shown that no other gases besides N_2, O_2, H_2, CO, CO_2, H_2O, can exist in appreciable quantities in equilibrium during the explosion and expansion stroke. Methane can be formed during the exhaust stroke, and also aldehydes if the mixture is rich. The ratio of carbon monoxide to hydrogen in the exhaust gases under different conditions can be calculated. If a paraffin petrol is used, the ratio H_2/CO is calculated as 0·4, whereas Bannatynes empirical rule gives 0·36. With aromatic fuels this ratio would be very different.

* Abstract of paper read before Section G of the British Association, Cardiff, August 25, 1920.

A HIGH SPEED INTERNAL COMBUSTION ENGINE FOR RESEARCH.*

By H. R. RICARDO.

IN the following paper the writer proposes to deal with certain experiments carried out on a high speed internal combustion engine which may, it is hoped, be of some interest. The engine in question, together with the testing gear, was designed by the writer in co-operation with Mr. H. A. Hetherington at the request of the Asiatic Petroleum Company for fuel research, and has been in constant use for the past ten months at the writer's laboratory at Shoreham. Sir Robert Waley Cohen, at whose instigation the experiments were carried out, maintained the very liberal point of view that no pains or expense should be spared in order to render them, not only of commercial value to his company, but also as far as possible of real scientific value, and, to this end he urged that the very finest experimental apparatus should be employed, and that every effort should be made to produce an engine capable of showing the highest possible power and thermal efficiency and which could, when required, run reliably at a piston speed in excess of that of existing engines, in order that the results obtained should not only be of a relative value but that their absolute value should be at least equal if not superior to, anything obtained hitherto.

After much consideration it was decided to construct a single cylinder unit of 4½-in. bore and 8-in. stroke, the main features of the design being:—

(1) The provision of means for varying the ratio of compression in the shortest possible time, and that while the engine is running on full load.

(2) The ability to run for long periods at piston speeds of from 2,000 ft. to 3,000 ft. per minute.

(3) The application of every known expedient in order to obtain the highest possible thermal, volumetric and mechanical efficiency.

(4) The provision of testing gear designed with a view to ease and rapidity of operation and the elimination as far as possible of the personal equation.

The most important consideration of all, however, was the attainment not only of reliability in the sense of freedom from breakdowns, but rather in the sense of mechanical consistency.

Before proceeding to deal with the results obtained, it may be of some interest to describe the general design of the engine and testing apparatus. (Figs. 1, 2, 2a and 3.)

First with regard to the variable compression the following considerations were taken into account:—

(1) That it must be possible to vary the compression rapidly, without disturbing any adjustments or temperature conditions and without altering the general form of the combustion chamber more than could possibly be avoided. After a good deal of consideration, it was decided to provide means for raising or lowering the whole cylinder bodily, together with the whole of its valve actuating mechanism, carburettor, &c. To employ a flat cylinder head with all valves fitted vertically in it so that the clearance space should be of a plain cylindrical form and, in order to ensure a reasonable depth of combustion chamber, even with a compression ratio of 8:1, a very long stroke is employed. The available range of compression ratio is from 3·7:1 up to 8:1. Throughout the whole of this range the surface-volume ratio varies only from 1·6:1 to 2·75:1, while the symmetry, compactness and general form of the combustion chamber undergo the minimum of alteration.

A very thorough investigation was made of the mechanical and other problems relating to high speeds, as a result of which it was found that the limiting factors were:—

(1) The loading on the connecting rod big-end bearing, due to the combined inertia and centrifugal forces, more particularly the latter.

(2) The actuation of the valves.

In order to reduce the inertia forces to the lowest possible limit an exceedingly light aluminium slipper type piston is used weighing only 2·45 lb. complete with gudgeon pin and three piston rings, but capable of standing a working pressure of 800 lbs. per square inch. The connecting rod is of hollow tubular form of heat-treated nickel-chrome steel having a yield point of about 180,000 lb. per square inch and, in order to reduce

*Paper read before Section G of the British Association at Cardiff, August 25, 1920.

the centrifugal loading on the big end bearing to the lowest possible limit, it was decided to abandon the ordinary split type of bearing which, on account of the bolts and bolt-bosses, is necessarily rather heavy, in favour of a solid big-end; this involved the use of a built-up crankshaft, but on the other hand had the advantage that a case-hardened steel crankpin could then be used. The big-end eye of the connecting rod is provided with a case-hardened steel bush and a thin and profusely perforated phosphor bronze bush is fitted floating freely between the connecting rod and crankpin in order to reduce the relative rubbing velocity. Oil under a pressure of 45 lb. per square inch is forced continually through the crankpin by means of a gear pump fitted in the base chamber, the oil thrown out from this bearing serving to lubricate the piston, gudgeon pin and all other working parts, except the valve gear.

As to the valve gear, particular care was taken to lighten the valves themselves, and the inertia of the valve actuating mechanism was reduced as far as possible by carrying the camshaft directly over the cylinder head. Five valves, two inlet and three exhaust are fitted, each operated by a separate cam and, in order to provide that the utmost use was being made of the material of the valve springs, care was taken to ensure that the rate of change of acceleration coincided as far as possible with the rate of the springs.

For the lubrication of the valve gear generally, oil is supplied under pressure through the hollow camshaft, from here it passes out through small holes drilled in the base circle of each cam on to the valve actuating rockers, and thence into the valve box; from the valve box it drains out into the bevel gear box and so returns to the crank chamber down the casing surrounding the vertical driving shaft. When running at normal speed the depth of oil in the valve gear box is about 1½ in., so that the valve stems and springs are almost entirely immersed. In spite of this, however, no oil appears to enter the cylinder by way of the valve stems. In fact the freedom from carbon deposit in the combustion chamber or on the valve heads has been a very noticeable feature throughout. This point is of some interest because there is a general belief among designers that the lubrication of valve mechanism must be much restricted on account of the passage of oil into the cylinders by way of the valve stems.

In order to obtain the best possible volumetric efficiency, ample valve area was provided, great care was taken to ensure that the best possible valve setting was used, especial attention was paid to the streamlining of the valve ports and passages, and to the elimination of any abrupt changes in direction or velocity. Finally, the inlet valves are "masked," that is to say, the seatings are recessed back, the diameter of the recess being only a few thousandths of an inch greater than that of the head of valve, so that during the first and last portions of its travel each valve functions as a piston valve, thus providing an extremely rapid cut off. (Fig. 3a.) The valves themselves are all made from 3 per cent. low carbon nickel steel, case-hardened all over. The stems are highly polished and run in close-fitting phosphor bronze guides.

To secure a high mechanical efficiency, piston friction is reduced as far as possible by eliminating all unnecessary bearing surface on the piston and by working always with a hot cylinder barrel. The whole of the water circulation is concentrated around the sparking plugs and valves the water in the cylinder barrel, being left stagnant. By this means the temperature of the cylinder barrel upon which the piston friction largely depends reaches a maximum very quickly and remains substantially constant, irrespective of the temperature of the circulating water. With the exception of the two ends of the connecting rod and the lower end of the vertical driving shaft, every moving part in the engine, including the crankshaft, is mounted on ball bearings. The main object of so extensive a use of ball bearings being to eliminate variables such as changes in friction due to the temperature and viscosity of the oil.

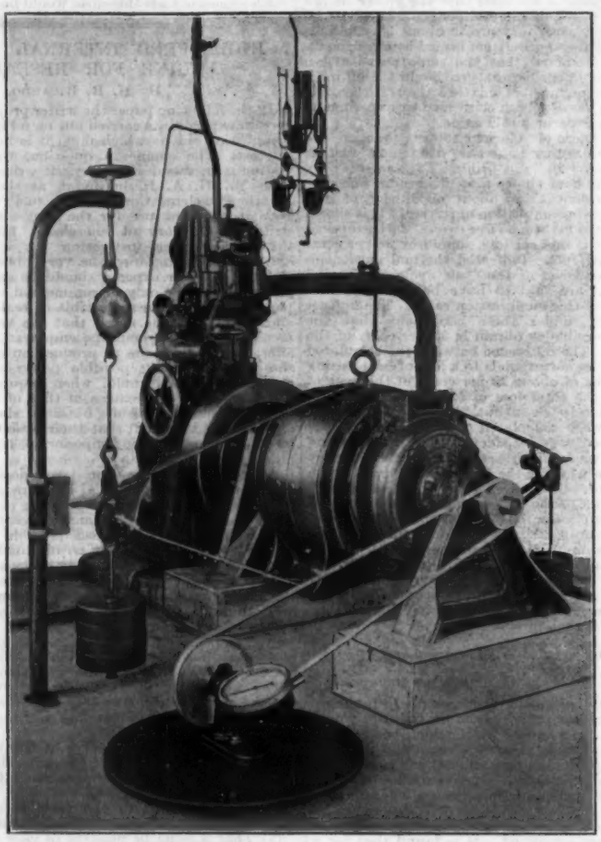


FIG. 1.

Frequent measurements of the mechanical losses are made by motoring the engine at normal working temperatures and recording the torque required to rotate it at various speeds; it was found, however, that after the first 40 hours no measurable change in the internal friction had taken place, further owing in part to the use of a stagnant water jacket and therefore a practically constant cylinder wall temperature, and in part to the ball bearings, the mechanical efficiency is nearly independent of oil or water temperature and experience has shown that little or no change in the mechanical losses takes place after the first 15 minutes running. This is a point which previous experience has shown to be of the utmost importance for, in the case of all other engines which the writer has used for experimental work it has invariably been found necessary to run the engine for long periods before the internal friction losses had settled down sufficiently to enable consistent readings to be taken. Four sparking plugs are fitted at equi-distant points round the circumference of the combustion chamber these are each connected to Remy high tension induction coils. All the coils are operated by means of a single low-tension contact breaker fitted at one end of the camshaft. The use of this system of ignition in preference to the ordinary high tension magneto system was decided upon for the following reasons:—

(1) By using a single contact breaker it was possible to operate all the sparking plugs in perfect synchronism.

(2) The time of ignition could be advance,or retarded without in any way affecting the intensity of the spark.

The mechanism employed for varying the compression is as follows. The outside surface of the cylinder water jacket is machined and ground and slides in a massive cast iron guide, it can be locked by a clamp bolt which closes in the guide and so grips the cylinder uniformly round the whole circumference of the jacket. The lower end of the jacket is screwed externally to receive a large phosphor bronze nut located between the lower face of the guide and the base chamber. This nut can be rotated by a hand wheel through the medium of bevel gearing and the cylinder bodily raised or lowered thereby. The nut and thread are amply strong enough to withstand the maximum pressure in the cylinder; but to ensure absolute rigidity, the clamp bolt in the guide is always tightened up when the desired position is attained and the cylinder held rigidly in a friction grip.

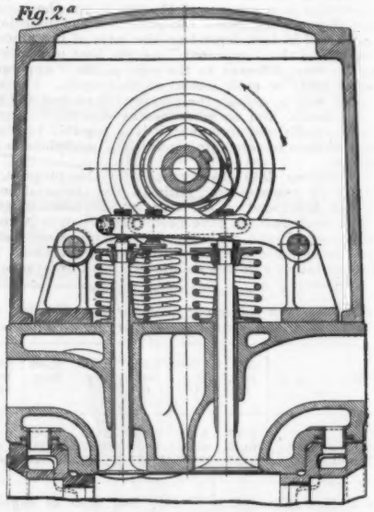
A micrometer with electrical contacts operating a small 4-volt lamp is fitted to indicate the exact position of the cylinder in its guide and therefore the compression ratio. (Fig. 4.) The valve gear is driven by means of a splined and telescopic vertical shaft. The total available travel is about 2 inches, corresponding to a range of compression from 3·7 to 1 up to 8 : 1.

The carburettor which is attached directly to the cylinder head and moves up and down with it is an ordinary standard Claudel but provided with an adjustable needle valve controlling the jet and an electrical heater fitted in the air intake pipe capable of absorbing a maximum of 2·5 kw., sufficient to vapourise the whole of the fuel and to raise the inlet air temperature to about 50 deg. C. if required. The heater is controlled by a fine adjustment rheostat, and is in series with the armature circuit of the dynamometer. A revolution counter is driven from the camshaft and is thrown in and out of operation by means of a magnetically actuated clutch which, in turn, is operated from a switch on the fuel measuring device so that the actual number of cycles during the consumption of a given quantity of fuel is automatically recorded.

The power is absorbed and measured by means of a swinging-field electric dynamometer, consisting of an ordinary shunt wound dynamo, the whole carcase of which is mounted on double row radial ball bearings. In order to give the machine stability the centre of gravity is kept very slightly below the centre of support. An arm extends from either side of the dynamometer, one end of which is connected to an oil dash pot and the other carries a weight pan and a spring balance. All pin joints in connection with the dash pot, weight pan, spring balance, &c., are fitted with radial ball bearings to eliminate friction. The dynamometer is in perfect balance when the arms are truly horizontal, and its stability is such that a displacement of ¼ in. above or below the horizontal mark on the pointer is equivalent to plus or minus 0·1 lb. on the scale pan. The scale pan carries a dead weight, which slightly exceeds the maximum torque of the engine, and a large open scale spring balance, graduated in twentieths of a lb. is employed to record the difference between the actual torque and the dead weight. The current generated in the armature is absorbed by a battery of iron wire resistances and the load is controlled and adjusted by means of two field rheostats, one having relatively coarse steps and the other a continuous wire coil resistance giving extremely fine graduations. The field current is supplied separately from the lighting circuit in the laboratory. The field control is extremely sensitive, about one complete revolution of the handwheel on the fine rheostat corresponding to a torque variation of plus or minus 0·5 per cent. (Fig. 5.)

The fuel measuring device consists of a pair of vessels each consisting of two conical chambers, one above the other, and provided with a gauge glass; the capacity of the upper chamber is exactly one pint and of the

Fig. 2.a



lower ¼ pint. A narrow neck is provided above and below each chamber, so that the fall of fuel in the gauge glass at the commencement and completion of each measured quantity is relatively rapid. While the average time taken to consume ¼ pint is in the neighbourhood of 80 seconds, the rate of fall past the marks on the gauge glass averages about 1 in. per second, so that extremely accurate observations can be made. Working with the ¼ pint vessel the accuracy of observation is within the limits plus or minus 0·4 per cent., and with the larger plus or minus 0·1 per cent. As the fuel in the gauge glass passes the upper mark the observer closes a switch which throws the magnetically operated counter into operation. On opening the switch as the fuel passes the second mark the counter is thrown out of gear and, by the same operation, a brake is applied to its spindle to prevent any tendency to over-run.

The arrangement and grouping of the apparatus is such that two practised observers and one assistant can operate the whole plant and take all necessary readings of temperature, torque, speed, fuel consumption, &c. (Fig. 6.)

In order to render the results of more general application, all the test figures are expressed in terms of indicated horse-power, the mechanical losses being determined by motoring the engine after each test. Very accurate measurements are obtained by adopting the following procedure.

Fig. 2.

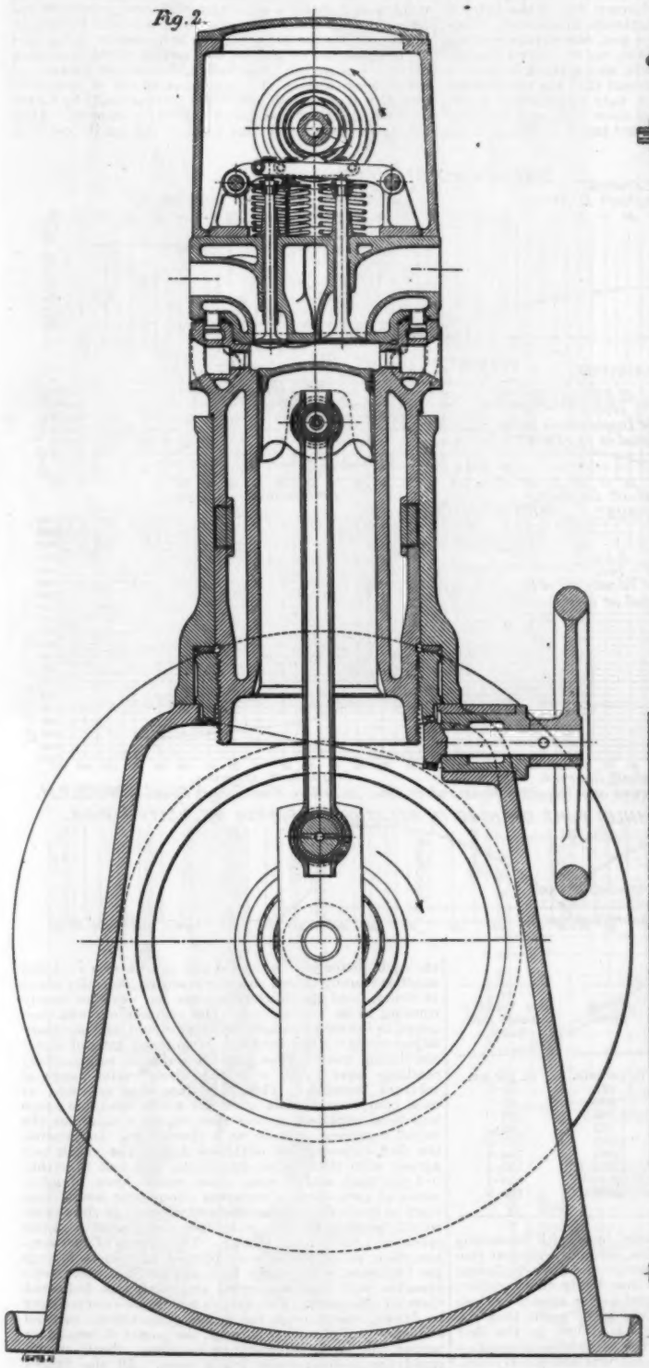
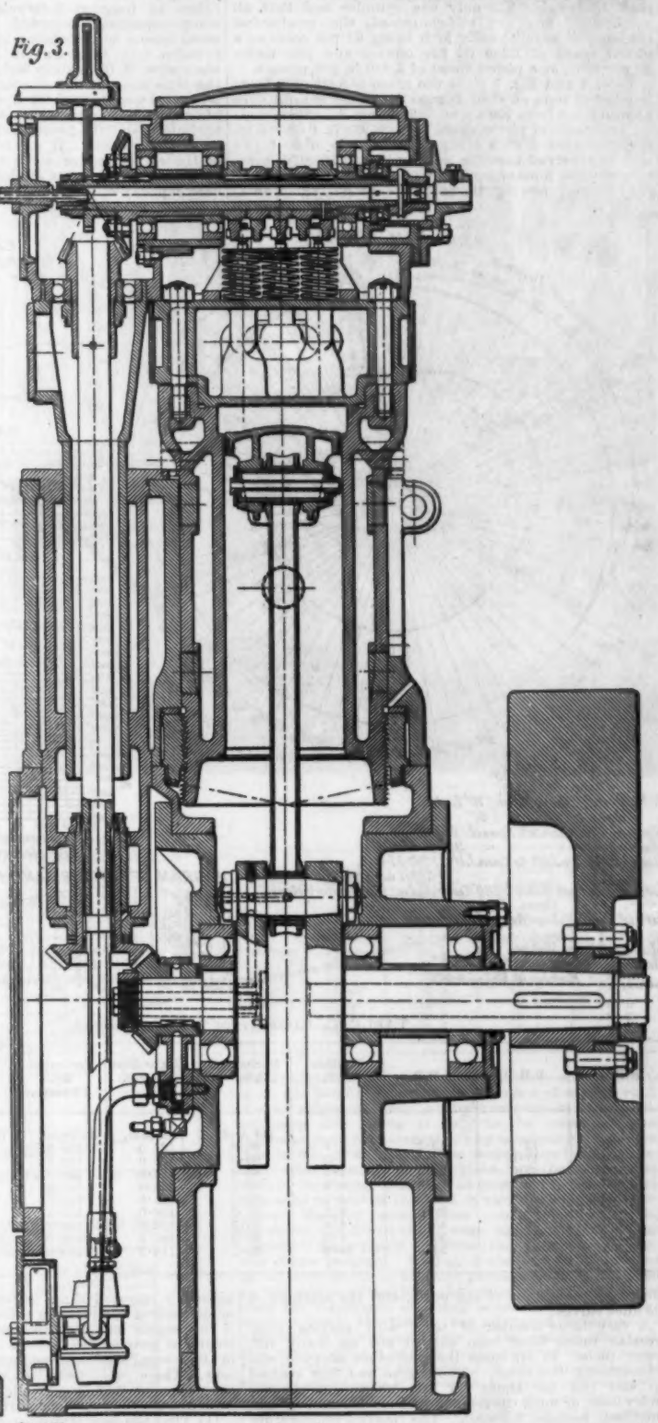


Fig. 3.



At the completion of each test, the supply of fuel and circulating water is simultaneously cut off and, as the engine shows signs of dying out, current is supplied to the armature and the speed maintained constant by means of the field rheostats. The torque required to rotate the engine is then measured on the spring balance attached to the dynamometer arm. The time taken from running on full load to motoring at the same speed is less than 30 seconds, during which period no measurable change in temperature can take place.

It may be argued that such measurements do not represent the actual mechanical losses when running under power because the bearings and pistons are not fully loaded. This argument, of course, is reasonable but, on the other hand, in the case of an engine running at such high speeds, the fluid pressure represents but a small proportion of the total loading on the bearings, &c.

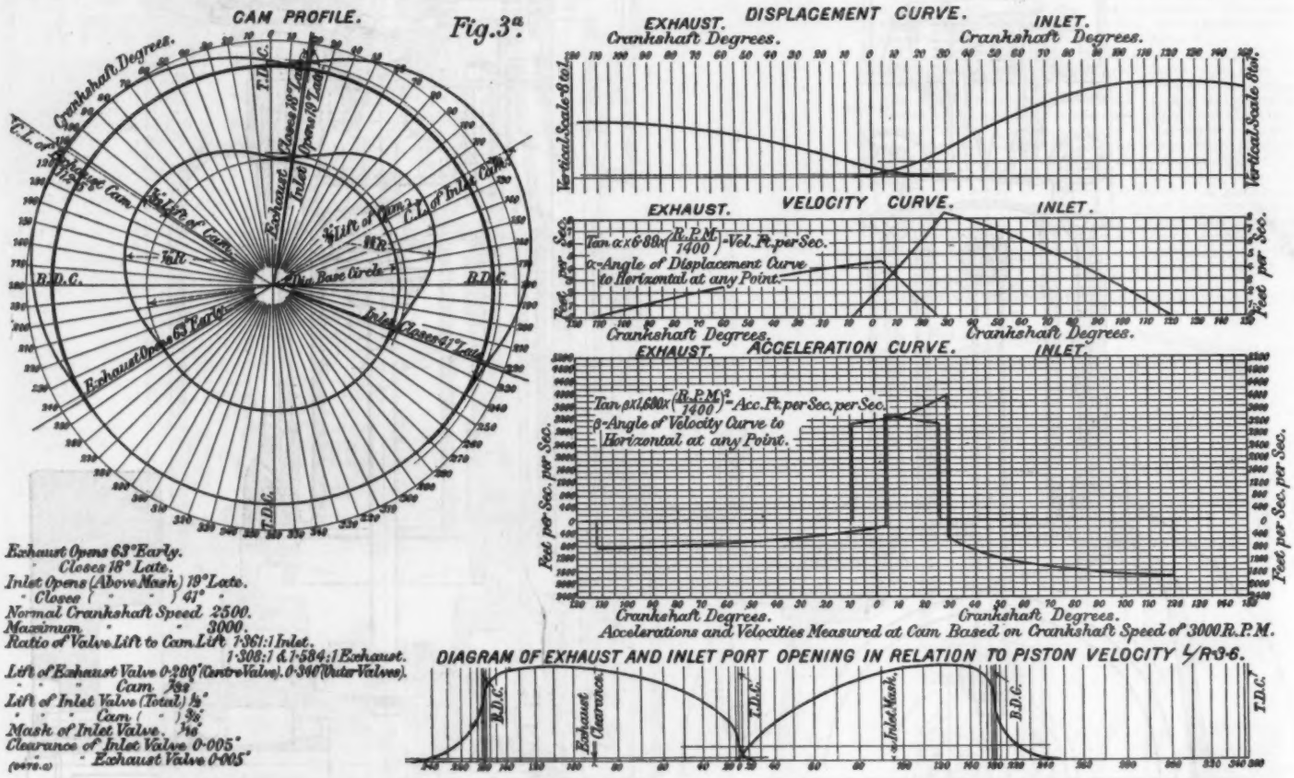
Again, when motoring, the fluid pumping losses on the exhaust stroke are higher, and there is some loss of heat on the compression stroke, these two factors just about balance the small reduction of load on the bearings, &c. Experience on many other engines in which other means have been available for measuring the mechanical efficiency has shown that, at high speeds, the motoring test is a very accurate one, and the writer is confident that the determination of the mechanical losses in this manner represents their true value when running to within very close limits. Further, the friction of

auxiliary drive windage loss, etc., have all been determined individually and are re-tested from time to time. During the first few months of operation a motoring test was made at the completion of every run, but experience showed that after the first 40 hours no measurable variation occurred, and the practice was discontinued except when the compression ratio, speed, throttle-opening, or some other controlling factor was altered or, as an occasional check test. It will be observed from Fig. 7 that in spite of the fact that the engine has only one cylinder and that all auxiliaries, &c., are self-contained, the mechanical efficiency is exceptionally high being 90 per cent. at a piston speed of 1,200 ft. per minute and just under 82 per cent. at a piston speed of 3,000 ft. per minute.

Table I and Fig. 7 gives the mean results of a large number of tests on shell Borneo petrol carried out over a speed range from 700 r.p.m. to 2,300 r.p.m., corresponding to a range of piston speed of from 933 ft. to 3,066 ft. per minute and with a compression ratio of 6 : 1. It will be observed that the indicated mean effective pressure reaches a maximum at a piston speed of 3,000 ft. per minute, showing the effect of ample valve area, constant at 1,500 r.p.m. corresponding to a piston speed of 2,000 ft. per minute, the throttle in all cases being wide open and the speed control effected by varying the field excitation of the dynamometer. So soon as the necessary adjustments had been made and the observer was satisfied that the conditions were, in every respect, normal, the clamp bolt locking the cylinder was slacked back slightly and the cylinder raised or lowered fairly rapidly, the speed meanwhile being maintained constant by adjusting the field excitation. Torque readings were taken at frequent intervals, and the corresponding compression ratios recorded. In this manner the maximum torque corresponding to the whole range of compression ratio from 4 : 1 to 7 : 1 could be explored in the course of 10 minutes and errors due to the entry of the time element almost completely eliminated. Three observers were needed for this test, one to take readings of torque and compression ratio, one to control the field excitation and the heater coils, and a third to raise or lower the cylinder. It was found that the temperature of the cooling water did not vary appreciably during such a test on account of the short time and the large heat capacity of the cylinder and jacket. This test was very large number of these rapid compression-torque tests were carried out on a number of different fuels, such as different petrols, benzol, alcohol, toluol, naphthenes, &c. Except that only a comparatively small number of fuels would stand so high a compression ratio as 7 : 1, the characteristic behaviour of all of them was found to be exactly the same over their available range of compression. In Fig. 8 is shown a characteristic curve of the relation between compression ratio and indicated mean pressure taken on benzol, it applies equally to petrol, within the limits possible with that fuel, and indeed, with but almost infinitesimal variation, to any other volatile hydrocarbon fuel.

For measuring the thermal efficiency at different compression ratios a somewhat different procedure was adopted. After the engine had been adjusted to develop maximum torque at any given compression ratio, and all temperature conditions had settled down, a reading of fuel consumption was taken, the actual number of revolutions during the consumption of a measured quantity of petrol being recorded automatically by means of the magnetically operated revolution counter. After taking one reading in this manner the needle valve in

Fig. 3a.


CAM PROFILE.
Crankshaft Degrees.
T.D.C.
Exhaust Closes 18° Late
Inlet Opens 19° Early
Exhaust
Inlet
C.L. of Inlet Cam
Lift of Cam
Dia. Base Circle
B.D.C.
Exhaust Opens 63° Early
Inlet Closes 41° Late
DISPLACEMENT CURVE.
EXHAUST.
INLET.
Crankshaft Degrees.
Vertical Scale 6 to 1
VELOCITY CURVE.
Tan α x 6·88 x (R.P.M./1400) = Vel. Ft. per Sec.
α = Angle of Displacement Curve to Horizontal at any Point.
Feet per Sec.
ACCELERATION CURVE.
Tan β x 1,680 x (R.P.M.²/1400²) = Acc. Ft. per Sec. per Sec.
β = Angle of Velocity Curve to Horizontal at any Point.
Feet per Sec. per Sec.

Exhaust Opens 63° Early.
" Closes 18° Late.
Inlet Opens (Above Mask) 19° Late.
" Closes (" ") 41° "
Normal Crankshaft Speed 2500.
Maximum " " 3000.
Ratio of Valve Lift to Cam Lift 1·361 : 1 Inlet.
1·308 : 1 & 1·584 : 1 Exhaust.
Lift of Exhaust Valve 0·280" (Centre Valve). 0·340" (Outer Valves).
" " Cam .206"
Lift of Inlet Valve (Total) ½"
" " Cam (") 3/8"
Mask of Inlet Valve .116"
Clearance of Inlet Valve 0·005"
" Exhaust Valve 0·005"

Accelerations and Velocities Measured at Cam Based on Crankshaft Speed of 3000 R.P.M.

DIAGRAM OF EXHAUST AND INLET PORT OPENING IN RELATION TO PISTON VELOCITY 1/R3·6.

TABLE I.—CALIBRATION TESTS OF ENGINE.

R.P.M.	B.H.P.	I.H.P.	Friction H.P.	Mechanical Efficiency.	Brake Mean Pressure.	Indicated Mean Pressure.	Piston Speed.	Gas Velocity through Inlet Valve.
				per cent.	lb./sq./in.	lb./sq./in.	ft. per min.	ft. per sec.
700	13·7	15·2	1·5	90·0	121·5	134·4	933	51·5
900	17·9	19·9	2·0	90·0	123·0	136·5	1,200	66·1
1,100	22·0	24·5	2·5	89·8	124·0	138·3	1,466	81·0
1,300	26·2	29·4	3·2	89·3	125·0	140·5	1,733	95·5
1,500	30·4	34·5	4·1	88·3	125·5	142·5	2,000	111·0
1,700	34·6	39·8	5·2	87·0	126·0	145·5	2,266	124·8
1,900	38·6	45·1	6·5	85·5	126·0	147·7	2,533	139·6
2,100	42·0	50·3	8·3	83·5	124 5	148·5	2,800	154·5
2,300	44·3	54·9	10·6	80·7	119·7	148·0	3,066	169·0

effective streamlining of the ports, and the masking of the inlet valves.

A very large number of tests with varying compression ratios have been carried out on many different fuels. In all cases the procedure adopted was substantially the same. The engine was first started up and run for about 20 minutes to 30 minutes under load, or until the temperature conditions throughout had become normal. The outlet temperature of the cooling water was maintained at approximately 55 deg. C. and great care was taken to ensure that the temperature of the working fluid measured near the inlet valves was maintained constant at either 10 deg. C. or 15 deg. C. according to the fuel used, by means of the electric heater in the air intake passage. The mixture strength was adjusted by means of the needle valve in the carburettor jet until maximum torque was obtained, and the best ignition point also was found. Throughout most of the tests the speed was maintained generally repeated three or four times with increasing or decreasing compression ratios, and, as a general rule if the engine had been run previously for a sufficient length of time to settle down thoroughly the variation in the several readings was found not to exceed 0·3 per cent. These rapid tests had the great merit that the time element was largely eliminated but, in the first experiments, they were open to the following criticisms :—

(1) That the best ignition point was not exactly constant for all compression ratios.

(2) That, on account of changes in the volumetric efficiency, which will be discussed later, the best needle valve setting for maximum torque was not constant at all compression ratios.

Later on, after prolonged tests had been made at each individual compression ratio, the precise ignition and carburettor settings corresponding to the development of maximum torque at any ratio were found and marked, so that these settings also could be rapidly adjusted. A the carburettor jet was closed one quarter of a turn and another reading taken, this was repeated generally about 10 times, until the mixture became too weak for steady running to be maintained. The compression was then raised or lowered a certain definite amount, the necessary adjustments to the ignition setting and rate of water circulation made, when another series of consumption readings were taken over the whole useful range of mixture strength. This procedure was repeated at each compression ratio until the whole available range had been explored, it was then repeated again at the initial compression ratio as a check test. In general, the fuel consumption obtained during the check test agreed with that taken during the first test to within 0·4 per cent. and in some cases much closer. Such a series of tests usually occupied about four hours from start to finish during the whole of which time the engine would be running with wide open throttle at a piston speed of 2,000 ft. per minute. The curves of fuel consumption so obtained were plotted in terms of pints per indicated horse-power hour against indicated mean pressure and then converted into terms of indicated thermal efficiency. From these results two curves may be drawn, one through the points of maximum thermal efficiency and the other through the points of maximum torque, the latter affording an excellent check on the rapid torque-compression ratio tests. All the figures given in the following table are corrected for barometric pressure and for inlet temperature (where such correction is required). During the last six months a very large number of such tests have been carried out by several different observers and on numerous different fuels. The extreme variation of the absolute values either for thermal efficiency or mean pressure has been in all cases less than 0·7 per cent. on any given fuel and less than 2 per cent. over the whole range of fuels tested, while no measurable variation can be detected in the

general characteristics of the curves either with different fuels or at different compression ratios.

Table II, which follows, gives a summary of a large number of tests carried out on benzol, the lower calorific value of which has been determined by Mr. Tizard to be 17,330 British Thermal Units per lb. or 19,100 per pint. This fuel was selected because of the high compression it will stand. Up to certain limiting compression ratios the figures are equally applicable for any fuel at the same inlet temperature.

An examination of the results reveals two very interesting facts :—

(1) That the efficiency relative to the air cycle rises with increase of compression.

(2) That there is no corresponding rise in the indicated mean pressure and that, in fact, the rise is actually considerably less than proportional to the air-cycle efficiency.

The first of these phenomena can be explained, and it is interesting and satisfactory to note that the figures obtained by actual test agree very closely with those arrived at by Mr. Tizard from theoretical considerations. That there is no corresponding increase in the mean pressure is by no means easy to explain. Consideration will show that where no mechanical or temperature changes have taken place, mean pressure and efficiency must rise hand in hand unless there is a change in volumetric efficiency, that a slight change in volumetric efficiency may occur is only to be expected, and indeed experiments carried out by measuring the depression in the choke tube of the carburettor indicate that some such change does take place, but that the magnitude of the change should be as great as repeated experiments have proved it to be, is very difficult to understand. Possibly some other consideration may be advanced which will throw some light on the very considerable discrepancy between the thermal efficiency and mean pressure. In Fig. 9 the writer has plotted in full lines the mean effective pressure actually obtained on test and in dotted lines that which would be obtained were the volumetric efficiency constant throughout the whole range. The theory was advanced that possibly pulsation in the exhaust pipe to the silencer might, at this speed, effect a change in the volumetric efficiency, but this theory was disposed of by carrying out similar tests at other speeds when, in all cases, substantially the same discrepancy was observed. In this connection it is interesting to note that another series of tests made on benzol at the same speed but with one inlet valve out of operation so that the inlet area was reduced to half, and the gas velocity through the inlet port thereby increased from 111 to 222 ft. per second showed an even greater discrepancy, the figures obtained on this series of tests being as given in Table III.

Here the discrepancy between the I.M.E.P. observed on test and that which might be expected, were the volumetric efficiency constant has increased from 12 per cent. to over 17 per cent. The absolute accuracy of results obtained with one inlet valve only in operation

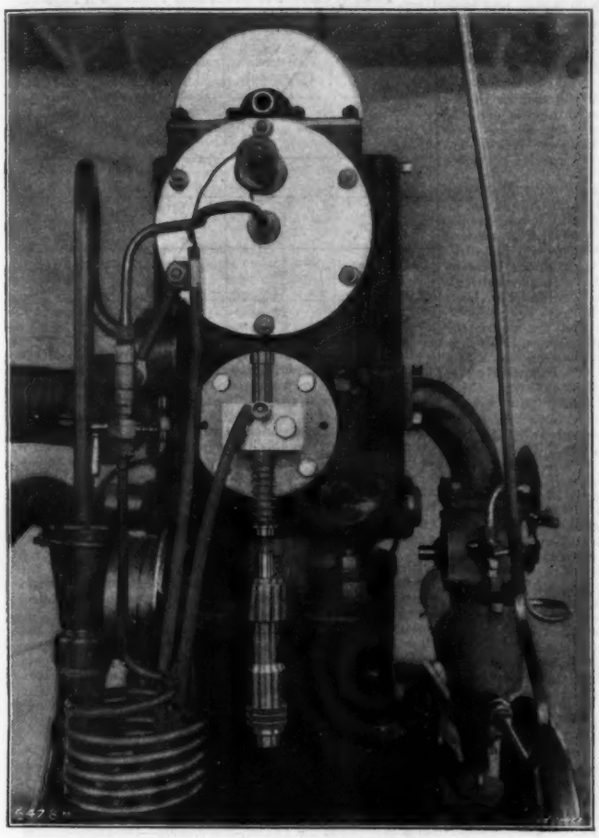


FIG. 4.

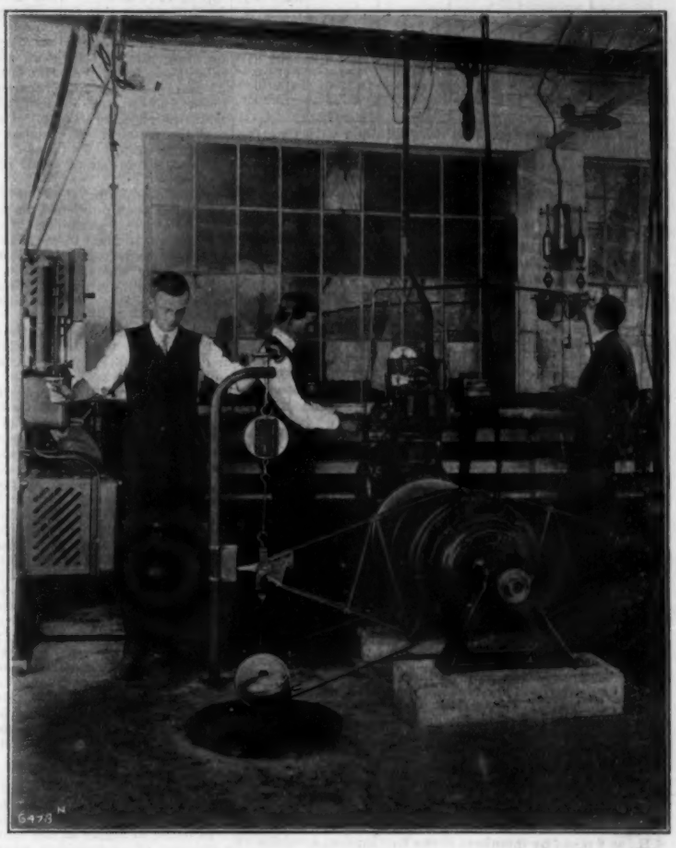


FIG. 5.

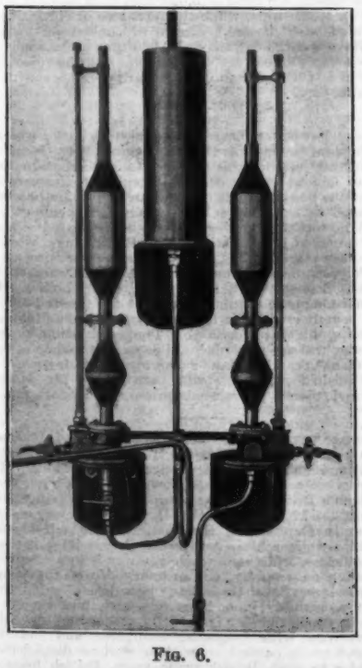
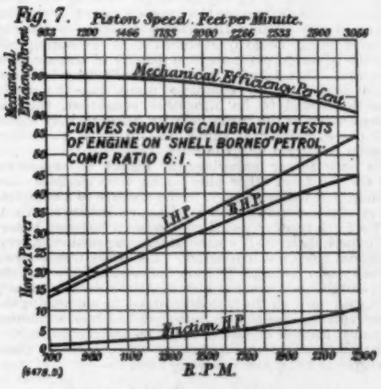


FIG. 6.



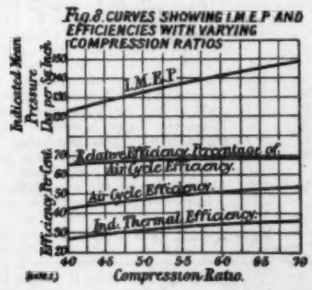


Fig. 8. CURVES SHOWING I.M.E.P. AND EFFICIENCIES WITH VARYING COMPRESSION RATIOS
I.M.E.P.
Relative Efficiency Percentage of Air Cycle Efficiency.
Air-Cycle Efficiency.
Ind. Thermal Efficiency.
Indicated Mean Pressure Lbs. per Sq. Inch
Efficiency Per Cent.
Compression Ratio.

TABLE II.

Compression Ratio.	Air-cycle Efficiency.	Indicated Thermal Efficiency.	Relative Efficiency.	Indicated Mean Pressure.
	Per Cent.	Per Cent.	Per Cent.	lb. per sq. in.
4·0 : 1	42·56	27·5	64·6	123·5
4·5 : 1	45·21	29·7	65·7	128·7
5·0 : 1	47·47	31·6	66·7	133·5
5·5 : 1	49·44	33·4	67·6	138·0
6·0 : 1	51·16	34·9	68·2	142·0
6·5 : 1	52·70	36·2	68·7	146·0
7·0 : 1	53·98	37·2	69·0	149·2

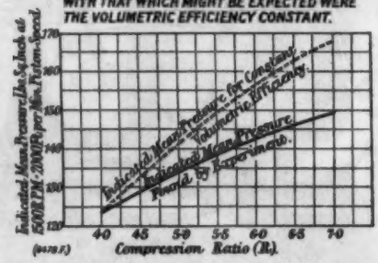
TABLE III.

Compression Ratio.	Indicated Thermal Efficiency.	Air-Cycle Efficiency.	Relative Efficiency.	I.M.E.P. Observed.	I.M.E.P. for Constant Volumetric Efficiency.
	per cent.	per cent.	per cent.	lb. per sq. in.	lb. per sq.in.
4·0 : 1	26·8	42·56	62·9	103·3	103·3
5·0 : 1	30·6	47·47	64·5	109·2	118·0
6·0 : 1	33·7	51·16	65·8	114·0	130·0
7·0 : 1	35·9	53·98	66·7	117·5	138·8

is not, however, so great as that obtained with two, for the following reasons :

(1) With one valve only in operation, the velocity through the carburettor is not sufficient thoroughly to pulverise the fuel, consequently a proportion is lost

Fig. 9. CURVE SHOWING INDICATED MEAN EFFECTIVE PRESSURE FOUND BY EXPERIMENT, COMPARED WITH THAT WHICH MIGHT BE EXPECTED WERE THE VOLUMETRIC EFFICIENCY CONSTANT.



by precipitation ; the proportion lost in this manner is small and probably constant, but a possible source of error is nevertheless introduced.

(2) When running with one inlet valve only the torque falls considerably between 1,470 r.p.m. and 1,530 r.p.m., so that the mean effective pressure varies considerably with the engine speed. It was found difficult on such a test to maintain the speed perfectly constant and a possible error amounting to as much as 1·0 per cent. in the torque reading may be introduced by accidental speed variations. This does not apply when the engine is operating with two valves for, between the same limits of speed, the torque is more nearly constant.

(To be continued.)

INSTITUTION OF PETROLEUM TECHNOLOGISTS.—The council have arranged for free illustrated lectures to be given in the Canada Building, Crystal Palace, London, S.E., at 6 p.m., by members of the Institution, as under : September 1, "Oil Prospecting," by Mr. G. Howell, F.G.S., F.R.G.S. ; September 8, "Petroleum Refining," by Mr. A. E. Dunstan, D.Sc., F.I.C., F.C.S. ; September 15, 'Utilisation of Volatile Oils," by Mr. W. R. Ormandy, D.Sc., F.C.S. ; September 22, "Utilisation of Heavy Oils," by Professor J. S. S. Brame, F.I.C., F.C.S.

THE SCANDINAVIAN FLEETS.—According to the statistics of Det Norske Veritas, 101 vessels of 219,000 tons, of which about 20,000 tons were built in Norway were admitted to Norwegian registry during the first half of 1920. Forty-two vessels were removed from Norwegian registry, leaving a net increase of 59 vessels of about 180,000 tons. Forty-seven vessels of 55,000 tons, of which 16,000 tons were built in Sweden, were admitted to Swedish registry during the same period, and the merchant fleet of Sweden increased by 9 vessels of about 29,000 tons. The Danish merchant fleet increased by 21 vessels of 28,000 tons. Of the 41 vessels of 39,000 tons, admitted to Danish registry, 21,000 tons were built in Denmark.

THE YENBERRIE METEORITE, AUSTRALIA.—The mass of 291 lb. of meteoric iron found in 1918 embedded in the sandy soil of the Yenberrie district, Northern Territory of Australia, has been analysed by J. G. Mingaye (Journal of the Washington Academy of Science, 1920, pages 314–316). The main metallic portion of the meteorite contains about 92 per cent. of iron, 6 per cent. of nickel, 1·5 of cobalt and traces of other constituents, among which is platinum ; tin and gold could not be detected at all. In the black covering of an internal nodule the iron percentage went down to 65, but there were 13 per cent. of sulphur and 4 per cent. of phosphorus and also 5 per cent. of carbon and 6 per cent. of oxygen. In turning the meteorite some lath-shaped, highly magnetic and extremely brittle particles were obtained ; they consisted of schreibersite (iron phosphide) and magnetite, and the oxygen contents in them rose to 12 per cent. ; there were also 2·5 per cent. of carbon. The nickel percentage was fairly uniform all throughout the meteorite. We add that a meteorite which last April was seen to fall in Kentucky, differs so strongly from the usual meteorites, that its character would hardly be suspected. According to G. P. Merrill, (Proceedings of the U.S.A. National Museum), it seems to be composed of fragments of two dissimilar stones, which are essentially magnesium silicates, containing the one 3 per cent., the other 12 per cent. of ferrous oxide, together with traces of 17 other elements.

PNEUMATIC ELEVATORS.*

By Professor WILLIAM CRAMP D.Sc.

PNEUMATIC elevators were invented in England ; the first practicable machines being those of F. E. Duckham, about 1897†, which were used for grain. Up to 1914 however little development had taken place in this country, but in Germany their design had been studied and their uses largely extended so that most of the chief ports of that country were equipped with one or more floating elevators and there were also many inland examples. At the outbreak of war on account of the necessity for transporting large quantities of grain quickly and economically for the armies in the field, their use received a great impetus in this country and the Government ordered several large plants costing more than 20,000*l.* each. The Office of Works also ordered a number of small plants for special purposes in 1918.

Notwithstanding these developments nothing of any value has been published on the action of the plants, or on the general principles of design and arrangement. From time to time there have been descriptive papers ; but tests and design data seem to have been jealously reserved by the constructors, and the writer believes that for the most part the designs have been empirical, otherwise many obvious mistakes would have been avoided.

The attention of the author was first drawn to this subject about 1913 when having made himself familiar with Continental practice he began a research which was interrupted by the war in 1915. Subsequently he approached, in 1918, the newly-formed Department of Scientific and Industrial Research which gave him a grant towards the expenses of a research to be carried out in connection with a plant provided by Messrs. Thomas Robinson and Sons, of Rochdale. The research was proceeded with, at Manchester University with the permission of Sir J. E. Petavel, and the work was largely carried out by Mr. A. Priestley, M.Sc.

The experiments were confined to wheat, this being a material frequently elevated by pneumatic means, and having fairly constant dimensions. The power required to elevate granular material at a given rate can be expressed in terms of the difference of pressure across the conveying pipe and the quantity of air per second moved under this pressure difference. The part of this which appears as useful power can be expressed in terms of the weight of material lifted per second and the height to which it is raised. The ratio of these two powers gives the efficiency of the plant. It is evidently easy to determine this experimentally, but there are great difficulties in formulating a satisfactory theory connecting the large number of variables in the appropriate equations. With a given current of air it is necessary to determine and connect reliable expressions for the following quantities :—

(1) The force, acceleration, and velocity with which the material is moved in air of varying density.
(2) The retarding forces on the material.
(3) The retarding forces on the air.

In order to arrive at the force acting on the material a number of experiments were made with special apparatus, and from these a factor was arrived at which, when multiplied by the square of the velocity of the air relative to the grain gave the force on each berry within certain limits. Using this factor a series of velocity distance curves could be deduced from the appropriate velocity equation assuming the density of the air to be constant. This velocity was then checked by measurements made on the complete plant, but the results were not found to be altogether consistent, the calculated value of the mean velocity being usually higher than the experimental value, due no doubt to friction between the grain and the pipe.

No satisfactory experimental means of separating this friction from other phenomena were available and ultimately it was necessary, in the absence of a complete theory of the motion of the particles, to deduce the value of this force from repeated comparisons between theory and experiment, until a satisfactory expression, having a rational basis was arrived at. The other forces acting in the system, viz., the friction between the air and the pipe, and that between the grain and the air were similarly dealt with until all the factors required for connecting the forces with the change of momentum had been accounted for and a general equation could be written down.

The final equation embodying the results of these experiments takes the following form :—

$$p_0 - p = \frac{L}{F}\left\{\left(2{\cdot}1 + \frac{A}{\sqrt{L}}S\right)V_f + B\frac{S}{V}\right\} + C\frac{V_a^2 S}{d} + D\,V_a^2.$$

Where $p_0 - p$ = Vacuum in cms. of mercury.
S = Length of pipe in metres.
F = Area of pipe in square cms.
A = Diameter of pipe in cms.
L = Grain lifted. Tons per hour.
V_f = Grain velocity at the top of the pipe in metres per second.
V_a = Air velocity at the top of the pipe in metres per second.

$$V_a = \sqrt{\frac{E}{\sqrt{L}}(V_a^2 - F) + F}$$

and

$$V_f = \frac{}{1 - \frac{E}{\sqrt{L}}}$$

* Abstract of paper read before Section G of the British Association at Cardiff, August 27, 1920.

† *Vide* ENGINEERING, January 29, 1897.

The constants A, B, C, D, E, and F depend chiefly upon the type of material which is being elevated and were all determined for the wheat used and the results were then checked against the actual figures obtained from experiments upon the complete plant. The results of this comparison are given in the following table :—

Table of Calculated and Actual Vacua for a Pipe 9 M. Long and 4.8 Cm. Diameter.

Tons per hour lifted.	Va. Metres per second.	Vacuum calculated cms. of mercury.	Vacuum measured cms. of mercury.
1·39	20	7·3	7·2
	30	10·5	10·8
	41	14·8	13·5
2·38	19	10·4	11·2
	33	16·1	16·8
3·72	19	14·6	15·3
	29	19·6	19·6
	37	24·6	23·8
4·85	18	17·7	18
	26	21·9	22·3
	34	27·4	26·4
6·3	27	27·4	27·5

In the course of the experiments the influence of the form of nozzle used became prominent. Tests were made therefore on a number of nozzles to ascertain the manner in which they influenced the behaviour of the elevator. It was found that for each type of nozzle there was a certain constant representing the number of tons drawn into the nozzle per hour per square centimetre of nozzle area per metre per second of air velocity at the nozzle calculated on the full nozzle area. This has an important bearing on the amount that a given plant can lift per hour. Since mechanical elevators can be designed to work with an efficiency of 75 per cent., it is very important that the maximum theoretical efficiency of a pneumatic elevator should be known and compared with its rival. If we regard the velocity energy of the grain as a loss, which is usually the case, then for various shapes of pipe giving different accelerations the theoretical efficiency cannot exceed 40 per cent. In practice no pneumatic elevator approaches this efficiency and yet they are used because of their labour saving qualities and freedom from dust. From the equations and experimental work it would seem that there is no reason why the efficiency of commercial plant should not easily be doubled, and if the results of this research are put into operation it seems certain that an improvement of this order will be effected.

THE GRANGESBERG COMPANY'S SHIPBUILDING ORDERS.—We read in *Swedish Export* that some time ago the Grängesberg Company entered into a contract with the Göta Shipyards for 18 iron-ore vessels—the largest order for ships that any Swedish shipyard has so far received. It is estimated that the first of these steamers can be launched very shortly, and yet another in four months. These vessels are both of 8,000 tons each and are being built as steamships, while the next two or three will be provided with motors. Eleven of the vessels ordered will have a cargo capacity of 8,000 tons each, while the other seven will load 5,000 tons each. All the vessels are to be of a special design, adapted to the requirements of ore transport.

HANS CHRISTIAN OERSTED.—July 21, 1920, was the 100th anniversary of the first publication by Hans Christian Oersted of his discovery in electromagnetism, and in honour of the occasion a special edition of his works has been brought out and an exhibition has been arranged at the Polytechnical College, Copenhagen, of which he was the founder. A statue of Oersted has also been unveiled in his native town, Rudkøbing ; wreaths have been placed on his grave by the present Director of the Polytechnical College, from the King of Denmark, the Danish Society of Science and other bodies. His original magnetic needle is shown at the Oersted exhibition, together with his first editions of these diplomas, portraits, his furniture, &c. The celebration proper, however, will not take place till September, when several important Scandinavian gatherings and lectures by distinguished scientists will take place. It is also proposed to erect an Oersted museum in Copenhagen.

TRADE WITH CHINA.—The department of Overseas trade has issued a report [Cmd. 853, price 9*d.*) on the conditions and prospects of trade with China. The report gives a list of the 50 open ports of China, those at which a British consulate is open being distinguished by an asterisk. It is stated that though the Government is nominally Republican, the country is in effect ruled by military oligarchies set up by the Provincial governors. Nevertheless, whilst the whole country is in a condition bordering on anarchy, the ordinary life of the people and the interests of trade have been less affected than might reasonably have been expected, and except in areas in which fighting is actually proceeding, or which are overrun with brigands, commerce and industry continue to be carried on without serious disturbance. In order to push British trade more, British firms of good standing, though not necessarily with large capital, are required to act as distributors. British merchants should, it is urged, travel more, and the younger generation should all learn Chinese.

AIRSHIPS FOR SLOW-SPEED HEAVY TRANSPORT AND THEIR APPLICATION TO CIVIL ENGINEERING.*

By Wing-Commander T. R. CAVE-BROWNE-CAVE, C.B.E., R.A.F.

In the paper presented at last year's meeting the author gave a summary of the work which had been carried out by airships during the war, and indicated in very general terms certain lines along which development was possible. Since that time it has been possible to consider to what commercial application the various operations carried out during the war lead.

Air Commodore Maitland has read to the Royal Society of Arts a paper which deals most completely with the question of mail and first-class passenger airship transport over long distances. The paper was considered so valuable that it was somewhat extended and more complete appendices, giving detailed estimates of cost, were added. It was then read to a meeting of members of both Houses of Parliament, which was very largely attended.

The development of the airship for service purposes is in itself an extremely important problem, and most interesting experiments are now actually in hand. It is not, however, possible to discuss these service proposals, at present at any rate, and this paper, therefore, will be confined to the remaining uses to which airships can advantageously be put.

It is not likely that the possibility of applying airship work to the problems of, say, civil engineering will present itself to the civil engineer because practical experience with airships is at present confined to comparatively few. The Air Ministry cannot—particularly at the present time—develop all sorts of aircraft operations in the hope that they may be useful to someone. A definite useful application must be clearly in view before experiments are justified. I therefore propose to describe certain applications which appear in the light of airship experience to be practicable and of value, and hope that these may suggest means of overcoming some actual difficulties. The following suggestions are somewhat speculative, but in each case the actual airship operation on which they depend has been carried out in practice, and it is thought that, as far as the airship is concerned, the proposals which are now made do not involve any unduly speculative features.

Type.	Capacity.	Length.	Beam.	Gross Lift.	Useful Load.		H.P. for 35 M.P.H.	Weight of Fuel per Hour at 35 M.P.H.
					As Airship with Crew and Machinery but no Fuel.	As Dumb Barge.		
	million cb. ft.	ft.	ft.	tons.	tons. Correct to about 10 per cent.	tons. Correct to about 10 per cent.	h.p.	lb.
Non-Rigid.								
S.S.Z.	0·07	143	40	2·1	0·73	1·3	26	15·5
C.	0·2	210	50	6·1	1·4	2·5	120	72·0
N.S.	0·4	262	54	12·1	6·4	7·8	170	102·0
Semi-Rigid.								
A.	0·6	320	64	19·0	12·8	14·5	200	120·0
PL. 26	1·00	520	65	33·5	23·5	27·0	500	300·0
T. 34	1·2	410	70	36·0	25·0	28·5	550	330·0
Rigid.								
R. 33	2·0	640	80	60·0	35·1	38·0	430	264·0
L. 71	2·4	740	85	73·0	48·1	52·0	500	300·0

In considering the applications of aircraft one usually thinks of the high-speed transport of light loads and has an instinctive fear that the load carried may really be too small to be useful. One never thinks of an aircraft as a low-speed weight lifter, but on investigation it will be found that the airship in suitable form has considerable possibilities in that way. The actual lifting capacity of an airship, exclusive of propelling machinery, fuel, crew, &c., is shown for various sizes on the table on this page. If it is proposed to use an airship for comparatively short distances and only at times when the wind speed is low and high speed of the ship is not required, the available lifting capacity then becomes large, even for a comparatively small and easily-handled ships.

In most parts of the world and especially at selected seasons, there is a large proportion of time in which the wind speed is not more than 20 m.p.h. In many places the variation of the wind during the day is quite regular, and operations may be planned so that the wind is favourable on both out and return journeys. Under these conditions a ship capable of, say, only 35 m.p.h. would prove quite a valuable form of transport, although so low a speed would be useless for a passenger ship that must run to time-table whatever the wind, or for a service ship that must work in all weathers. The table shows the dimensions of the various types of ship that have actually been built and the loads they would carry at an air speed of 35 m.p.h. These same ships when used as dumb barges having no machinery, and fuel would carry the loads shown in column 7. No actual data exists for the reduction of speed by towing another ship, as the resistance of the towing wire is somewhat unknown, but theoretically an airship capable of 35 knots alone would have, when towing one barge similar to herself, a speed of 28 knots, and with two barges 24 knots.

This operation of towing one airship by another was actually carried out at Farnborough before the war, when one small airship having broken down was towed home by another. The towing airship "A" landed close to the damaged one "B" and 600 ft. of wire was attached to "A" and to "B." Both ships were made light and "A" was released first. She gradually rose into the air, and as the wire drew taut, "B" was similarly released. "A" then went ahead and towed "B" home to Farnborough without any difficulty whatever. There was an officer in "B" to steer and adjust pressure, but no difficulty in control was experienced. The landing was equally simple. On reaching the landing ground the wire was dropped by "A" and secured by a landing party, who hauled down "B." The airship "A" then landed as soon as the landing party was ready to receive her. This operation was only done once, and that it was so completely successful indicates that, with practice, the towing of even several "dumb barges" could be satisfactorily carried out under more difficult circumstances.

In 1914 an expedition against the Mad Mullah in Somaliland was contemplated, and an airship expedition from Berbera was planned. It was intended to establish the airship base on the high ground behind Berbera, but, as the intervening country was very difficult even for a camel, schemes were prepared for transporting the stores and machinery for this base, including the gas plant, by means of an airship towing another envelope loaded as a dumb barge. This expedition was, however, abandoned for a reason we did not then understand.

We have, therefore, available the possibility of transporting considerable loads over impassable country and depositing them on open spaces which, provided they give sufficient reasonably flat ground on which the airship may land, require to be nothing in the nature of the firm flat aerodrome as usually understood in connection with aeroplanes. The application of this possibility to various engineering problems is most interesting.

1. *Development of Railways in New Country.*—I understand that during the construction of a railway through really difficult country the expense and delay involved through having to work entirely from the railhead is very considerable. At the time that one is digging through a hill it is extremely difficult to dispose of the spoil, and, when crossing a valley, it is difficult to find sufficient spoil to fill up the valley and build an embankment. If it were possible to distribute one's steam navvies and other machinery at suitable intervals along the railway by dividing them up into parts weighing, say, 10 tons or 15 tons, and transporting it by air, not only would immense time be saved by delivering the attack at several points, but the operation in itself would be very much simpler, as work could be arranged so that the disposal of the spoil was very much easier.

2. *Prospecting for Oil and Minerals.*—One of the greatest difficulties in carrying out a thorough prospecting survey for, say, oil in new country, is the transport of the machinery to the points proposed. The machinery required for this purpose can certainly be broken up into sufficiently small units to be easily transported by some of the airships and barges shown in the table. As a regular means of transport across a belt of inaccessible country an airship, towing if necessary barges, should be a very valuable vehicle. I understand that in many places in South America, for instance, there is a belt of 400 miles or 500 miles of totally impassable forest which separates districts of extraordinary wealth in gems, gold, &c., from railhead. As the transport of such articles is not necessarily a matter of high speed, and as it need not be independent of weather, the form of transport I suggest should have many interesting applications.

It is also quite possible to land one or more men from an airship and to pick them up again without the assistance of a landing party. This makes it possible to land a surveying party and keep them supplied with stores, provisions and comforts, and, when their work is done, pick them and their instruments up and return them to the base. For geographical surveys, scientific exploration of a country, zoological research, &c., &c.—this operation has very great possibilities.

The Canadian Government contemplate using small airships for forest patrol to discover and give warning of fires which at present are often not detected until they spread to considerable extent and become very difficult to deal with. If dealt with promptly their suppression is, I believe, easy. For fishery patrol the airship has also very great advantages over all other craft and also over other aircraft.

Many of the operations described above are essentially suitable for ships of moderate size. They do not, therefore, call for great expense in first construction of the ship and of the terminal station from which she works. Slides are shown to indicate the various methods of housing a ship at the terminal station: the airship shed, the mooring mast, and the mooring-out ground used during the war. The plant and supplies needed at a terminal station include nothing of a special character except the provision of a mooring mast or shed, a gas plant, and a supply of fuel for the ship.

The type of gas plant most suitable for any particular case depends upon the local facilities. Hydrogen may be prepared from coke by a water gas process, or by electrolysis if electric power is available. The production from ferro-silicon and caustic soda may have advantages in some special cases. A modification of the present water-gas process in which wood may be employed instead of coke, is under consideration.

The number of men required to handle and operate a ship is commonly believed to be large, but with the aid of most primitive mechanical appliances a 500-ft. rigid has been safely secured to the mooring mast with the assistance of only six men on the ground. In considering fast long-distance passenger and mail routes large ships and high speeds are necessary, and the system must be capable of working in all weathers. The number of passengers and the quantity of mails is at first problematical and the institution of such a service requires firm resolution and great confidence.

It seems, however, that there must be many problems in connection with engineering and scientific activities where the data is definite, the problem easy, and the amount of money involved in the experiment comparatively small—very small indeed compared with the sum expended on works of this nature and to which these operations would be an auxiliary. Experimental work would no doubt be necessary in connection with any particular project, but until the requirement is stated and the conditions known nothing much can be done to advance beyond the experience which already exists. I hope that this paper may suggest applications which will assist projects now in contemplation and that the outline description given has indicated what is practicable at once.

* Paper read before Section G of the British Association, at Cardiff, on Friday, August 27, 1920.

ABSORPTION OF MOISTURE BY COKE.—According to some experiments made by W. A. Selvig and B. B. Kaplan, of the United States Bureau of Mines at the Pittsburgh Station, the hygroscopicity, especially of by-products coke is sufficiently great to affect the results of analyses and the value of estimates based upon the analyses. The cokes tested were a beehive foundry coke and three kinds of cokes from by-product coke ovens. The latter proved far more hygroscopic than the beehive coke. In an air of a relative humidity of 50 per cent. the by-product cokes absorbed more than 1 per cent. of moisture within one hour; after six hours there was no further increase in the amount of moisture absorbed, but a by-product coke had absorbed 1·7 per cent. of moisture under conditions where the beehive did not take up more than 0·4 per cent. of moisture. The different by-product cokes differed as to their hygroscopicity; as the humidity of laboratories fluctuates considerably, the point should not be overlooked, especially in the determination of the percentage of volatile matter.

COAL SUPPLIES IN BRITISH MALAYA.—Official statistics to hand from Singapore reveal interesting facts in regard to the coal supplies of the Straits Settlements. The following table shows quantities and value of imports and exports in 1918 and 1919:—

	1918.		1919.	
	Tons.	Value. £	Tons.	Value. £
Imports ...	510,100	2,878,800	503,541	2,281,751
Exports ...	369,288	2,160,236	487,924	2,245,726

This represents chiefly bunker coal, which accounts for the relatively large amount of exports. A comparison with the statistics of 1913 brings out two outstanding features—the falling off in shipping requirements at Straits Settlements ports in the more recent years and the greatly increased price of coal supplies. In 1913, no less than 1,080,454 tons were imported at a value of £1,325,470. Some years before war broke out coal had been discovered in the Malay Peninsula, in the States of Perak and Selangor. The coal found at Rawang, in Selangor, some 25 miles from Kuala Lumpur, the capital of the Federated Malay States, proved to be of first-rate quality, and, as prospects showed a supply of over 10,000,000 tons, the Malayan Collieries, Limited, was formed to work it and place it on the market. The difficulty of getting plant during the war hindered development; but mining was started in earnest in 1915, when 11,523 tons of coal were obtained. Down to the end of 1918—the latest year for which figures are obtainable—437,388 tons had been mined, and the quantity would have been greater but for lack of plant, shortage of labour and epidemics of sickness amongst the workers. The output in 1916 was 101,846 tons; in 1917, 155,279 tons, and in 1918, 168,740 tons. This discovery of indigenous coal is likely to have an important bearing on local industries, which, hitherto, have had to rely mainly on fuel supplies from the native forests. It is interesting, therefore, to note how the 168,740 tons mined in 1918 were disposed of, which is shown below:—Federated Malay States Railways, 67,437 tons; tin mines, 66,500 tons; other Federated Malay States consumers, 14,915 tons; exported, 19,888 tons. This is the first record of coal being exported from the Federated Malay States. A royalty of 25 cents (7d.) a ton is charged by the Government, but there is no export duty on the coal. So far, no steps have been taken to mine the coal discovered at Enggor, in Perak.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

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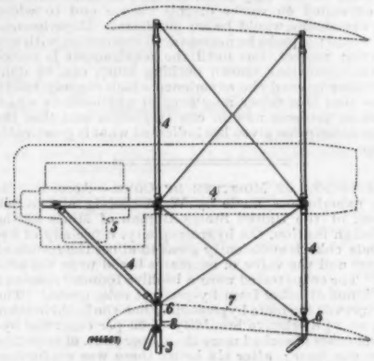
AERONAUTICS.

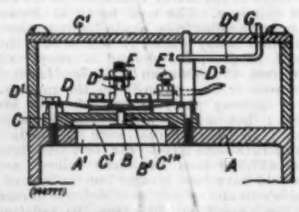
144,867. F. Handley Page, London. Aeroplanes. (2 *Figs.*) December 4, 1915.—The invention relates to aeroplane flying machines, in which the landing or supporting gear is directly connected to framework carrying the engine and other parts. According to the invention, the heavier portions of the aircraft, such as the engine and the fuel and oil tanks, are carried by a structure located above the lower wings, and connected by rigid connecting members passing directly through said wings with the chassis of the landing gear located beneath said wings, so that the shocks upon the landing gear will be directly transmitted



to the wings. The landing gear comprises, landing wheels carried through the medium of shock-absorbing devices and struts 3. Above the lower wing 7 is a structure 4 which supports the heavier parts of the machine, such as the engines 5, and the lower ends of the members of the structure are connected to spindles 6 which pass entirely through the lower wing 7, with a certain degree of freedom, and the lower ends of the spindles 6 are connected beneath the lower wing 7 to the struts 3 of the landing gear, and thus the said framework 4 is directly connected by the rigid members comprising the spindles 6 with the landing gear located beneath the wings. Tubular sleeves 8 pass through and are fixed to the spars of the wings, and the spindles 6 extend through such sleeves. (*Accepted June* 30, 1920.)

ELECTRICAL APPARATUS.

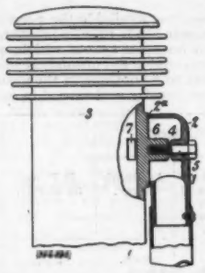
144,777. Harvey, Frost and Co., Limited, London, and W. H. Welch, Bristol. Electrical Cut-out. (3 *Figs.*) March 13, 1919.—The invention is for improvements in pressure-operated electrical cut-outs applicable to portable vulcanisers in which steam as the heating medium is generated by electrical means, and it is desired that the temperature shall be regulated automatically by repetitive cutting off of the current whenever a predetermined pressure is reached in the generator. According to the invention, in a pressure-operated electrical cut-out having a bow spring to control the pressure member by thrust from the central part of the bow spring, the bow spring is thrust towards the pressure-operated member by screws, one at each end, which screws are separately adjustable. The plate A represents one wall of the pressure chamber, which, in a vulcaniser, is the steam generating chamber. In this wall is an opening A1 which is covered by a diaphragm B, of resilient material clamped in place by a cover plate C. The cover plate is hollowed at C1 on the side



which is towards the diaphragm, to allow free movement of the latter, but is not so deeply hollowed as to prevent the diaphragm from bearing against it when thrust in to the limit of its movement; the plate thus serves as a support for the diaphragm. Above the cover plate is a bow spring D, the centre of which bears upon a thrust-piece B1 which extends through a hole C1* in the cover-plate and presses against the diaphragm. The bow spring is held in place by screws D1 and D2, one at each end, which extend through the spring and are carried by the cover-plate. These screws are adjustable in the cover-plate so that by screwing them further in, the tension of the spring on the diaphragm may be increased, or by drawing them out, it may be decreased, and the screws can be separately adjusted. A contact arm E of resilient metal extends transversely across the bow spring D, being carried by a block on the cover-plate, and a thrust-piece D3 on the top face of the bow spring bears against the underside of this contact arm at a point near its root. This arm has a connection for one wire of the electrical circuit, and its free end make contact with another contact-piece, which is also carried by the cover-plate C, but is insulated therefrom and provides another connecting point E2 for the electrical circuit of the heating element. The screw D2 has a laterally-projecting arm D4, whose end projects through a slot G in one wall G1 of the casing, within which the whole apparatus is enclosed. On this wall along the slot is a scale marked in pounds per square inch. As the pressure in the generating chamber rises the thrust against the diaphragm B increases until the spring D is thrust back sufficiently to cause the thrust-piece D3 carried thereby to lift the contact arm E and thus separate its free end from the contact. The circuit through the heating element of the vulcaniser is thus broken and the generation of steam ceases. As the apparatus cools down, the contact will again automatically come into operation, and so the apparatus may be kept automatically at any desired temperature for as long a period as is required. (*Accepted June* 30, 1920.)

GAS ENGINES, PRODUCERS, HOLDERS, &c.

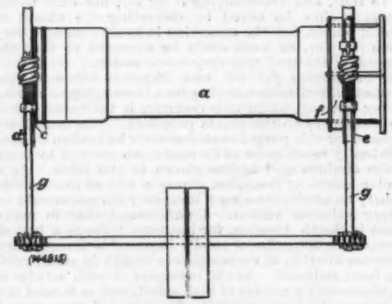
144,494. W. J. George, Birmingham, and L. Bircumshaw, Birmingham. Exhaust Pipes. (3 *Figs.*) July 12, 1919.—The invention relates to exhaust pipes of internal-combustion engines and comprises an exhaust pipe which has a pivotal connection at its junction with the exhaust ports. By slackening the said connection, the exhaust pipe can be readily removed for cleaning the exhaust ports, or the exhaust pipe can be swung round on the pivot pin and set at any angle required for its accommodation. The exhaust pipe 1 is provided with a cap 2 at its junction with the cylinder 3, the said cap 2 carrying a central and integral inner boss 4 through which a screw pin 5 freely passes. An outwardly-projecting boss 6



is cast on the cylinder 3 between the exhaust ports 7, and so as to be concentrically opposite the boss 4 on the cap 2, the screw pin 5 from the cap 2 being adapted to engage the said boss between the exhaust ports, and so bind the abutting edges 2a of the cap against the exhaust port face. By slackening the pin 5 in the cap 2, the abutting edges 2a are eased from the exhaust port face, when the exhaust pipe can be swung round upon the pin 5 to any angle required and fixed in that position by screwing up the said pin. By unscrewing the pin from the boss between the ports, the exhaust pipe is detached from the cylinder for cleaning the exhaust ports or for repair of the exhaust pipe or other purposes. (*Accepted June* 23, 1920.)

MINING, METALLURGY AND METAL WORKING.

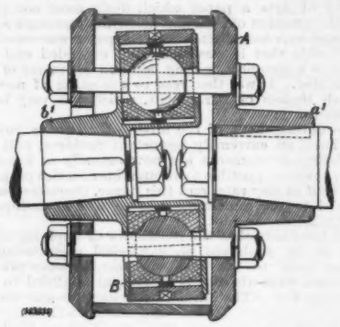
144,815. E. H. Summers, Gloucester, and E. S. Whittard, Stroud. Rotary Furnace. (2 *Figs.*) March 21, 1919.—The invention comprises certain improvements in rotary furnaces and retorts, and refers particularly to the driving mechanism therefor, of the type in which the drive is transmitted at more than one point in the axial length of the retort. The invention consists in the application of a positive drive, transmitted from a common source of power, at a plurality of axially-separated points, in conjunction with a device for taking up at one end longitudinal expansion of the retort. A retort in the nature of a horizontally located metallic cylinder *a*, is supported at or near to each extremity upon a bearing roller. Near its rear end the retort is furnished with two annular projections *c* which forms a run-away for the said roller at that end, so that axial derangement of the retort in relation to the roller is avoided. At its extreme rear end the retort carries a fixed worm wheel *d*. At or near



its front extremity, the retort is encircled by a worm wheel *e* adapted to slide axially upon the retort. For convenience in assemblage this worm wheel may be split. The worm wheel has rearwardly a sleeve-like extension *f*, flanged at its rear edge, and the periphery of which sleeve-like extension is adapted to bear upon a bearing roller. The bearing roller by co-operation with the flange locates the worm wheel, and the front extremity of the retort is adapted under expansion to move axially within the worm wheel. Said front part of the retort may be splined, and the inner surface of the worm wheel correspondingly recessed. Each worm wheel encircling the retort is in mesh with a worm provided upon a shaft *g*, which also carries a worm wheel; the worm wheel upon these two shafts are in mesh with worms provided upon a common shaft which may be parallel with the axis of the retort. This common shaft carries fast and loose pulleys, by which power may be imparted to it from any appropriate source. (*Accepted June* 30, 1920.)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

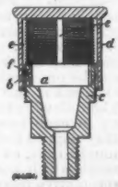
143,654. W. Ayer, Bangor. Universal Couplings. (3 *Figs.*) March 7, 1919.—The invention relates to universal couplings which are adapted to transmit rotary motion from the one part to the other whilst permitting axial and angular movement between them. According to the invention, such couplings comprise two members adapted respectively to be connected to and to rotate the shafts; one of the said members has one or more pins or bars rigidly fixed thereto so that the axis of each is parallel with, but displaced relatively to, the axis of the shaft to which the member is coupled, and on each of which pins a ball having a diametral bore fitting the pin is adapted to slide; the other of the said members has mounted thereon one or more radially movable spherical bearings adapted to fit the said ball or balls; motion is transmitted through the said pins, balls and bearings, and the axial movement of the balls and the radial movement between the parts connected by the couplings A and B are the two coupling members, bosses *a*1 and *b*1 of which are of taper bore and are fitted and keyed on the tapered ends of the respective shafts, which ends are provided with screwed extensions to take tightening nuts. The pins, of which there are three, are carried by the flange A formed integral with the boss



*a*1 and a flange rigidly secured to the flange A by means of distance sleeve and bolts; opposite ends of the pins are screwed, and the pins are held in place by nuts. The balls are diametrically bored to be a sliding fit on the pins. The member A is the driving member; the driven member is provided with three extensions B, each having a cylindrical bore radially disposed; within each of the bores a pair of cylindrical blocks are located, the adjacent faces of which have hemispherical recesses to form spherical bearings fitting the respective balls; the ends of the bores are closed by screwed caps, and spiral springs are interposed between a block and cap, and between a block and the bottom of the bore; clearance holes in the coupling member B and in the blocks are formed to permit the passage through the member B and the blocks of the pins. By radial movement of the spherical bearings and by axial movement of the balls on the pins, angular and axial movement between the driving shaft and the driven shaft are permitted. (*Accepted June* 9, 1920.)

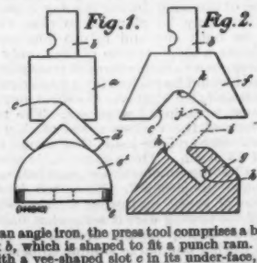
MISCELLANEOUS.

144584. J. A. Ross, London, and L. F. Brockman, London. Grease Cups. (2 *Figs.*) February 17, 1920.—The invention relates to grease cups of the type in which grease is forced out of the cup by screwing down the cap thereof and in which a spring finger carried by the cup engages one of a plurality of slots or their equivalents in the cap. The spring finger is formed out of a narrow strip of sheet steel which is bent longi-



tudinally to a circular or ring shape so that it will engage the interior of the cup when it is sprung into same, and by forming on the outer face of the said strip, by stamping or pressing, a small circular projection which is adapted to pass through a hole drilled in the wall of the cup and engage with one of the slots in the cap. *a* designates the spring ring, *b* the finger thereon, *c* the grease cup, *d* the screw-down cap of the cup, *e* the slots in the said cup, and *f* the hole in the cup through which the finger *b* projects. (*Accepted June* 23, 1920.)

144,843. J. F. Tinkler, Sunderland. Bevelling Angle-Iron Bars. (4 *Figs.*) May 2, 1919.—The invention relates to devices whereby the standard angle of angle-iron bars may be varied to any degree. The means according to the invention, consist of a press tool having a vee slot, the sides of which constitute an angle which is not less than a right angle and a pair of die blocks, one of which is formed with a semi-circular face for increasing the angle of the bar disposed thereon, whilst the other is formed with an angularly-disposed slot adapted to receive one side member of the angle iron for decreasing the angle thereof.



To open out an angle iron, the press tool comprises a body portion *a* and a shank *b*, which is shaped to fit a punch ram. The body *a* is formed with a vee-shaped slot *c* in its under-face, which slot is adapted to engage the angle iron *d*. This angle iron is supported by the semi-circular body *e*1 of the die block *e*. Referring now to Fig. 2, the press tool *f* therein shown is constructed similar to the press tool illustrated in Fig. 1. For closing up an angle iron, the die block *g* of different construction is employed and is formed with an angularly-disposed slot *h* to receive one side member of the angle iron *i*. The top edge *j* of the angle iron should come directly beneath the apex *k* of the vee-shaped slot *c*. (*Accepted June* 30, 1920.)